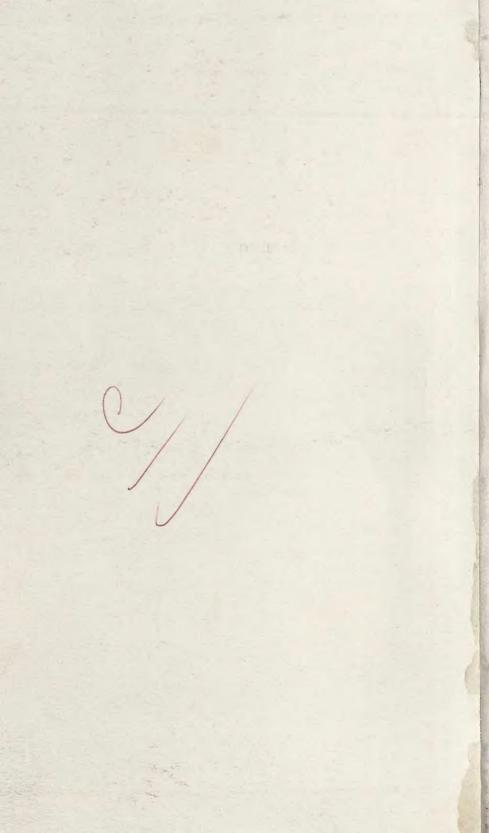


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CONSTITUTION OF INDIA PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC AND TO SECURE TO ALL CITIZENS:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the unity and integrity of the Nation:

IN OUR CONSTITUENT ASSEMBLY THIS TWENTY-SIXTH day of November, 1949, do HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.

FUNDAMENTAL RIGHTS UNDER THE CONSTITUTION OF INDIA RIGHT TO EQUALITY

- ♦ The state shall not deny to any person equality before the low or equal protection of the law.
- ♦ The state shall not discriminate against any citizen on the ground only of religion, race, caste, sex, place or birth.
- ◆ There shall be equality of opportunity for all citizens in matters relating to employment or appointment to any office under the state.
- ♦ Untouchability in practice in any form is forbidden and punishable.

RIGHT TO FREEDOM

- ◆ To freedom of speech and expression.
- ◆ To assemble peaceably and without arms.
- + To form associations or unions.
- ♦ To move freely throughout the territory of India.
- ♦ To reside and settled in any part of the territory of India. ◆ To practice and profess, or to carry on any occupation, trade and business.
- ♦ To provide for Right to Life and Personal Liberty, except according to procedure established by law.
- ♦ State shall provide free and compulsary education to all children of the age of 6-14 years in a manner to be determined by the state.

RIGHT AGAINST EXPLOITATION

- + Prohibition of traffic in human beings and forced labour.
- ◆ No child below the age of fourteen years shall be employed to work in any factory or mine or engage in any other hazardous employment.

RIGHT TO FREEDOM OF RELIGION

- ◆ Every person in India shall have the freedom of conscience and shall have the right to Profess, practise and propagate religion, subject to public order.
- ◆ No person shall the compelled to pay any taxes, of any particular religion.
- ♦ No religious instruction shall be provided in any educational institution wholly maintained out of state fund.

CULTURAL AND EDUCATIONAL RIGHT

- ♦ Any section of the citizen residing in the territory of India or any part thereof having a distinct language, script or culture of its own shall have the right to conserve the same.
- ♦ No citizen shall be denied admission into any educational institution maintained by the state or receiving aid out of state fund on the ground only of religion, race, caste, language or any of them.
- ♦ All minorities, whether based or religion or language, shall have the right to establish and administer educational institution of their choice.

RIGHT TO CONSTITUTIONAL REMEDIES

◆ The Constitution guarantees the right to move the Supreme Court for the enforcement of the fundamental rights through certain constitutions writs, such as: Habeas Corpus, Mandamus, Certiorari, Prohibition and Quo-Warranto.

Fundamental Duties of Indian Citizen

ARTICLE 51A

- Fundamental Duties It shall be the duty of every citizen of India (a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;
- (b) to cherish and follow the noble ideals which inspired our national struggle for freedom;
- (c) to uphold and protect the sovereignty, unity and integrity of India;
- (d) to defend the country and render national service when called upon to do so;
- (e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;
- (f) to value and preserve the rich heritage of our composite culture;
- (g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;
- (h) to develop the scientific temper, humanism and the spirit to inquiry and reform;
- (i) to safeguard public property and to abjure violence;
- (j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endevour and achievement.
- (k) who is a parent or guardian to provide opportunities for education to his child on, as the case may be, ward between the age of six and fourteen years.

A TEXT BOOK OF

BIOLOGY

[Higher Secondary & Joint Entrance]

♦ VOLUME I ♦

Including MCQ

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Revised, Enlarged and Updated Fourth Edition

2007

BOOK SYNDICATE (P) LTD

KOLKATA

Published by: Sri Biplab Bhowal for Book Syndicate (P) Ltd. 35 College Street Kolkata 700 073



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Par Bondary & Joint Entrance

First Published: June, 2000 Second Edition: April, 2004 Third Edition: March, 2005

Revised, Enlarged and Updated Fourth Edition: January, 2007

[New Syllabus]

Text Layout

Sri Subrata Bhowal

Illustration

Sree Shankhadweep Neogi

LEER V. W.B. ASSEAS 6.4.2007

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DE ARTIP KUMAR MITHA, MSE, Ph.D. EGS, ENRS, DES GONDS

Text Composed by: Sri Ashis Chowdhury for Raghunath Press Kolkata 700 006

Price: Rupees Three Hundred only

PCC 1 2153 14

Printed by :

Sri Bikash Pal

for Mudran Bharati

26 Madhusudan Banerjee Road

Kolkata 700 049

PREFACE TO THE FOURTH EDITION

It gives us a great pleasure in presenting the updated version of our existing book "A Text Book of Biology" Vol I. The book has been written by a balanced team of professors specialized in Plant Science, Animal Science and Human Biology. The main features of this book are:

- Simple lucid language with adequate illustrations.
- Large number of comparative accounts.

out the book

- A compandium of recent informations including key words, important discoveries, special questions.
- Graded exercise ear-marked with article number.

This book also contains additional solved questions including multiple choice type questions [MCQ] suitable for any medical entrance examination in the appendix. In line with the revised H.S. syllabus, the chapters on Taxonomy and Population Biology and Social Physiology have been incorporated in place of chapters on Photosynthesis and Growth.

The incorporation of extra illustrations on all chapters in the form of coloured plates has made the book outstanding. It is now up to our readers to judge how far we are successful in this venture. We are sorry for any kind of printers' devil, and any constructive criticism will be gratefully acknowledged.

We are deeply indebted to Mr. Biplab Bhowal, without whose co-operation and participation, this venture would not have been possible. We acknowledge the help of the press and office staff of Book Syndicate Pvt. Ltd., specially Mr. Subrata Bhowal, without whose active support, this book would never have been a reality.

are indebted to Mr. Biplab Bluwal, Managing Director, Book Syndicate Private

PREFACE TO THE THIRD EDITION

It is our great pleasure to present this revised third edition of the book entitled 'A Text Book of Biology' as the stock of the second edition of the book has been exhausted. In this edition, minor changes have been made in some chapters to cope with the current trends of the subject. In the appendix, we have incorporated answer to some special questions of various kinds e.g., long answer type, short answer type, distinguish between type and specially multiple choice type for the benefit of the students.

We are thankful to M/S Book Syndicate Pvt. Ltd. for publishing this revised edition within a very short time and also to those who gave us suggestions regarding revision of the book.

PREFACE TO THE FIRST EDITION

The present book 'A Text Book of Biology (Volume I)' has been written by a balanced team of experienced professors from the three disciplines of Biology-Botany, Zoology and Physiology. It is written for the students of +2 courses as well as for other competitive examinations. It essentially reflects the current trends of the subject.

After analyzing the present trend of questions set in different competitive examinations including the Medical Entrance Examinations of different states, particularly West Bengal, we have incorporated numerous critical and important topics. The following are the salient features of the book:

- The language of the book is very simple and lucid for clear understanding of the subject.
- Large number of comparative accounts have been given.
- Charts and Tables are given wherever necessary.
- Special care has been taken in preparing illustrations.
- The key words and biological terms have been highlighted at the end of important topics for revision.

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- Recent updated informations have been incorporated.
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- 2. Summary

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- 3, Naming / Discovery / Discoverer
 - 4. Answers to Special Questions was soon and trought a relative thousand
 - 5. Graded Exercise, ear-marked by article numbers for relevant answers have been given for the benefit of the students.

We are indebted to Mr. Biplab Bhowal, Managing Director, Book Syndicate Private Limited for his patience and encouragement. We offer our sincere thanks to the press and office staff, specially Mr. Subrata Bhowal, who worked hard to bring out the book in time. Despite our sincere efforts, some printer's devil might have crept in for which we are extremely sorry. Any constructive criticism for improvement of the book will be gratefully acknowledged.

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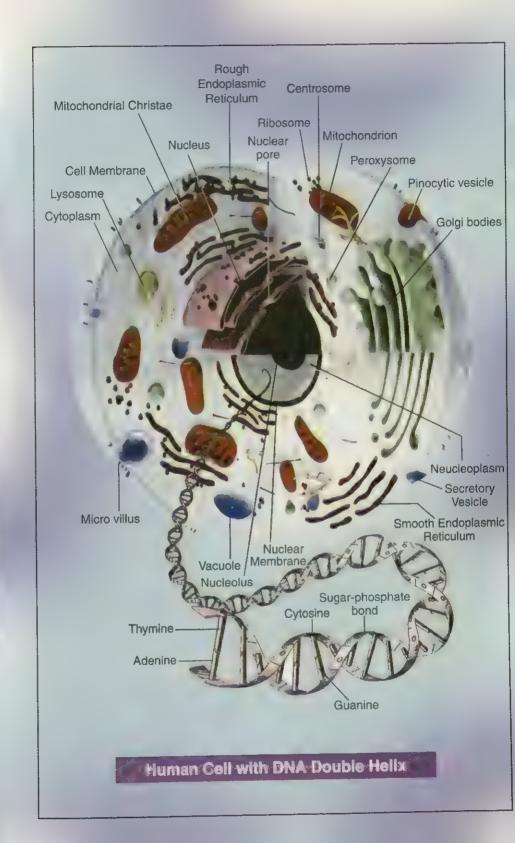
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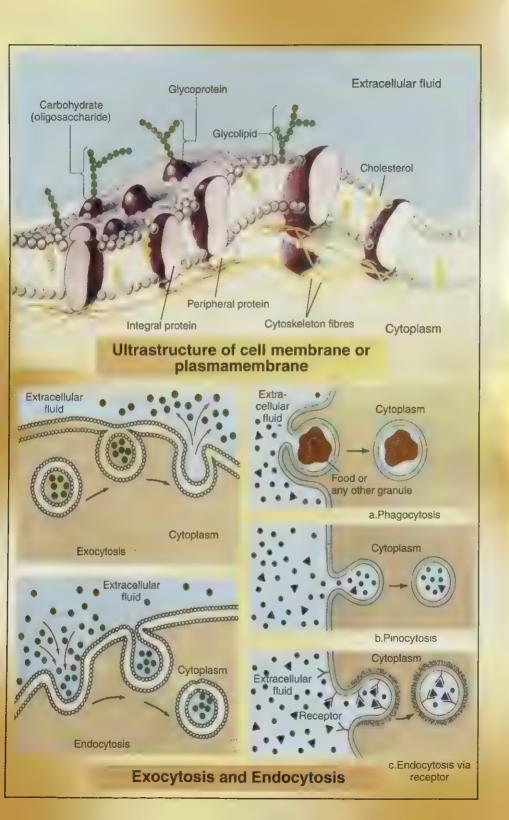
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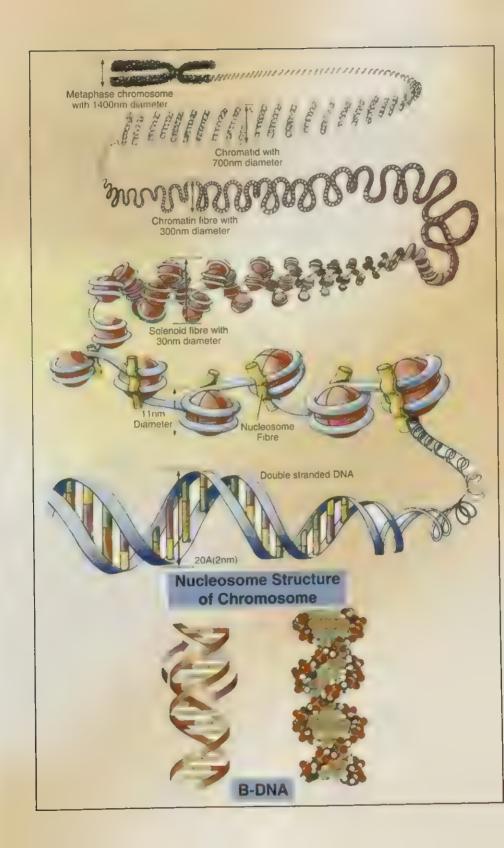
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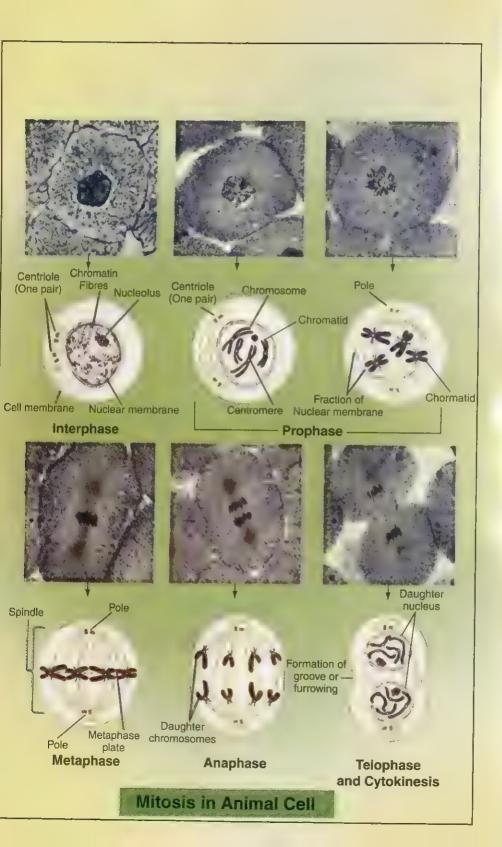
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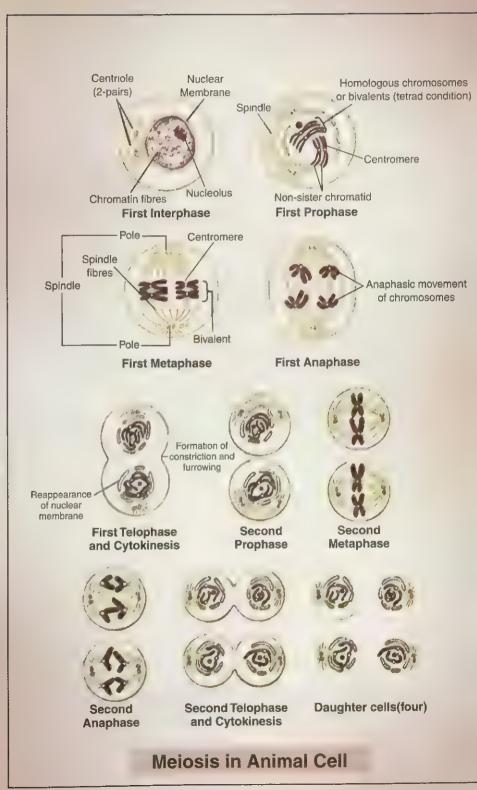
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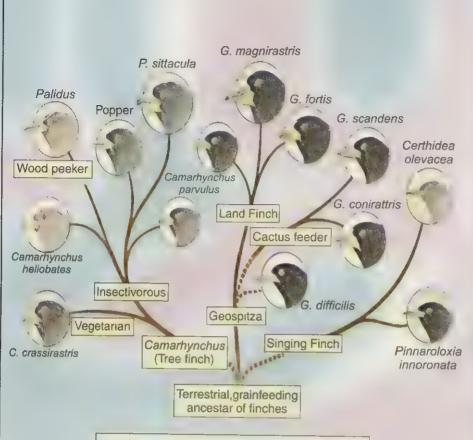












Phylogenetic tree of Darwin's Finches



Australopithecus

Homo habilis

Homo erectus

Neanderhal man

Homo sapiens (Modern man)

Human Evolution



Skull of Australopithecus



Lower Jaw of Australopithecus



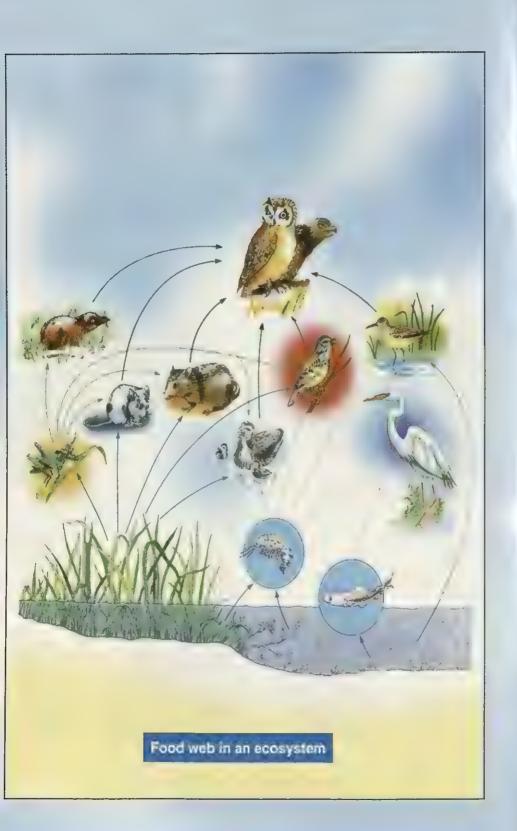
Skull of Homo habilis

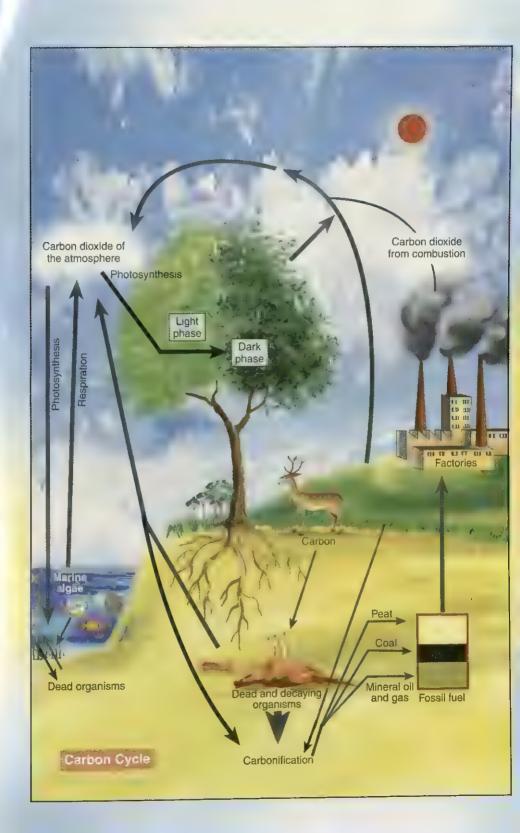


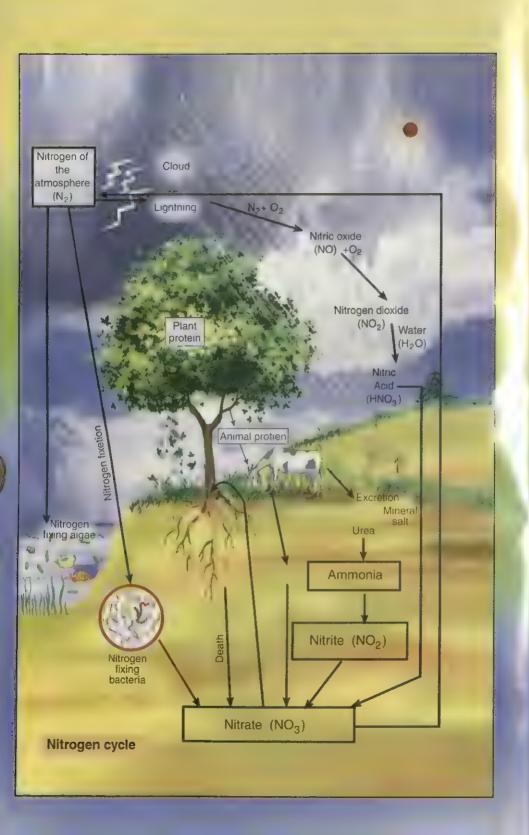
Skull of Homo erectus

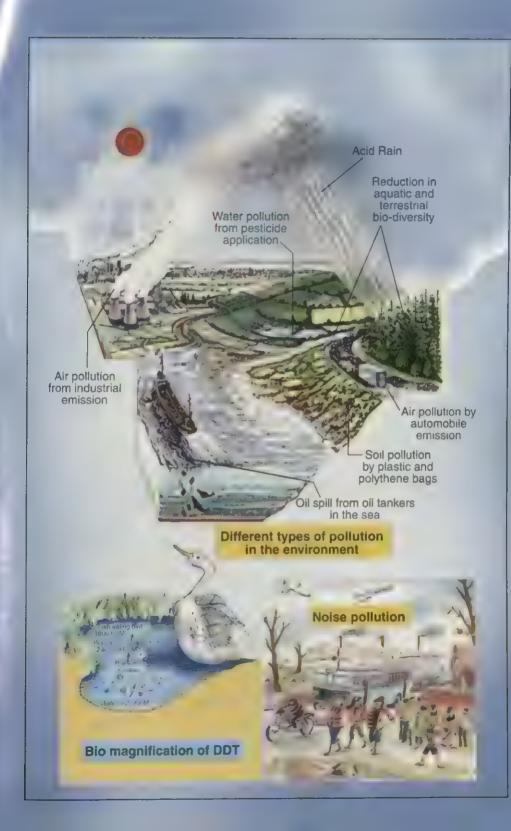


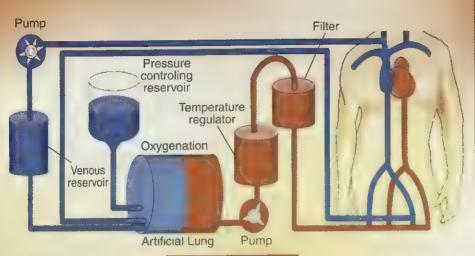
Evolution of Human Skull







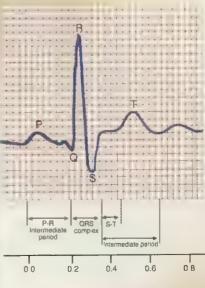




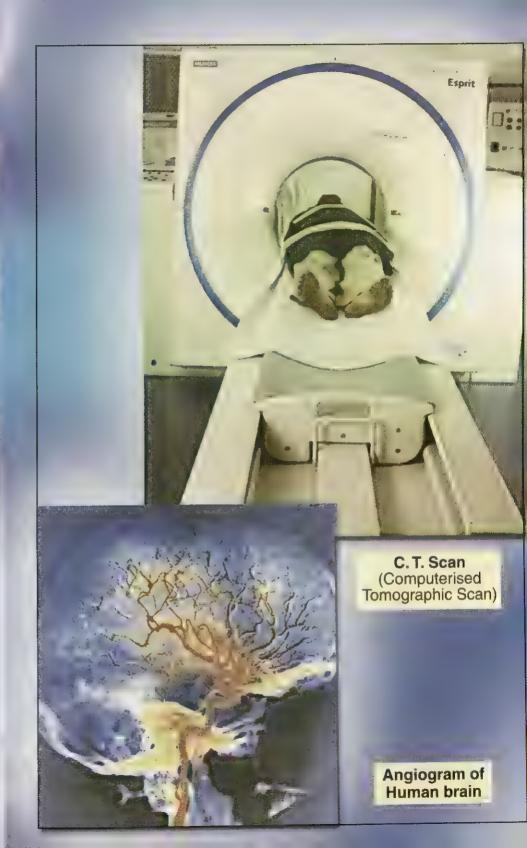
Heart Lung Machine

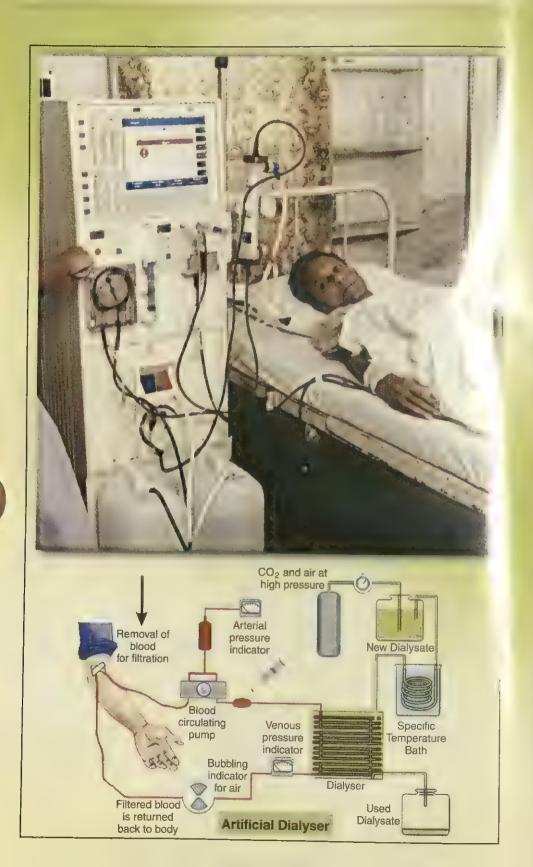


Electro Encephalogram(E.E.G.)



normal Electro Cardiogram





Nature and Scope of Biological Sciences

Topics Discussed: Introduction, Biology: Science of life, Status of Biology, Biology in ancient period, Biology and its relation to other Sciences, Scope of Biology, Importance of Biological Sciences in this millennium, Different branches of Biology.

INTRODUCTION

Fundamental concept of Biology is concerned with life. But what life is or what is the definition of life, in real sense still remains unexplained. Arsitotle, a great philosopher and naturalist identified the plants and animals as living objects. But he failed to give the accurate definition of life. Though the real mystery of life is yet to be revealed, the life manifests itselt through its various activities.

Life can be compared with the flame of a candle. The flame is produced by the combustion of candles which is nothing but chemical reactions. Just like the flame, due to chemical reactions within the body, the characteristics of life are manifested externally. The flame will persist as long as combunstion continues in the candle. As soon as the combustion materials of the candle will exhaust, the flame will also extinguish. Similarly in the living body if the sources of material, from where the energy is produced, are exhausted, then the life will also cease to exist.

As the flame of a candle emits continuous light and releases heat energy, so also manifestations of life depend upon the continuous release of energy from the living body. Energy is the source of all functions. This energy in the living body are of two types, potential energy and kinetic energy.

The potential energy is stored in the living body by the physiological process. This potential energy is again converted into kinetic energy by the chemical reactions. The kinetic energy is utilised in the various activities of a body and due to this, various characteristics of life are expressed.

1.1. Biology: Science of Life

It is very difficult to define life, though we can realise its existence in the living body. Life may be assumed as some power which remains in some substance and is expressed through some external manifestations. We can say that life is easier to recognize than to define. So life can easily be inferred from the activities of the organisms. No single definition alone is enough to put forward a precise definition of life. Biologists have given several definitions about life.

- [1] Life may be defined as the external manifestation of the actions and interactions between the environment and its protoplasm.
- [2] Characteristic features in the growth, reproduction, sensitivity, mutation and evolution of complex organic cellular substance is known as life.
 - [3] Life may be defined as the well organised dynamic complexity of substances.

Characteristics of Life

It is very difficult to give the exact definition of life. But life can be recognised through expression of certain activities and these activities are manifested in the process of metabolism, growth, movement, irritability and reproduction. Therefore to a biologist, the word 'life' means the properties of life and these properties are the characteristics of living organisms. The characteristics of life or living body are discussed below:

[1] SHAPE AND SIZE:

Every living organism has its own shape and size. Man, dog, horse, mango tree etc. have their own definite shape and size. A rat will never look like a dog or a mango tree will never attain the size of a banyan tree. But in case of non-living or in-animate objects there is no definite shape and size, rather they transform into different forms. As for example, water is a non-living object, but if it is placed in a container, it takes the shape of that specific container. In nature, it may exist in a pond or a river or as a mass of cloud or as an ice block. It is the same water which remains in pond, river, cloud or ice block, but in different forms and sizes.

[2] PROTOPLASMIC COMPOSITION:

All living organisms are composed of *protoplasm* which is a living substance. Protoplasm is a jelly-like semi-fluid substance, which is confined in a cell. It is composed of organic and inorganic materials. In a watery medium of protoplasm, organic substances like carbohydrates, proteins and fats and variety of inorganic salts are present.

Protoplasm is basically same in all living organisms. Throughout the life time of an organism, the protoplasm remains active. Death of the protoplasm means death of the organism. So it is the basic material of life.

[3] ORGANISATION OF BODY:

All living bodies are made up of small units, and these units are known as cells. A cell is an organised mass of protoplasm. Some of the organisms have only one cell while others have many cells. Single celled organisms carry out all the vital activities in an well organised manner. So, a cell is not only a structural unit but also a functional unit as well. In the multicellular organisms, the organisation is more developed as well as complex in nature. Here groups of cells are organised into tissues and different types of tissues make up an organ such as stomach, lung etc. Several organs work together act as a system and the different systems constitute an organism. So, a living body of higher grade of organisation consists of many organs and systems which act harmoniously for the benefit of the entire organism.

[4] METABOLISM:

In the protoplasm of the living body, a series of chemical changes are constantly taking place, and the sum total of these biochemical changes is collectively known as *metabolism*. The metabolic changes occurring in protoplasm are of two types—anabolism and katabolism (catabolism). The process by means of which the simple food particles are stored in the protoplasm is known as *anabolism*. In this process, new materials are added in the protoplasm and in these materials, potential form of energy is stored for future use. For this reason, anabolism is regarded as the **constructive phase of metabolism**. Thus, photosynthesis and nutrition are regarded as anabolic processes,

through which the protoplasm is built up. On the other hand, the process by means of which the stored potential energy of the protoplasm is converted into kinetic energy is known as *katabolism*. In this process, different materials of the protoplasm are destroyed and lost. For this reason, katabolism is regarded as the destructive phase of metabolism. Respiration is regarded as the katabolic process. In this process, energy is released in kinetic form which is utilised in the life process of the organism. So both the constructive and destructive phases of metabolism continue side by side in the protoplasm. The metabolic changes are being expressed in various activities of the living body such as nutrition, respiration, secretion and excretion.

[a] Nutrition:

Nutrition is an anabolic process. All organisms derive energy through nutrition, as because a living body requires energy to carry out its activities. The food is the fuel of the living organism. So, both the plants and animals derive energy from food. Among the living organisms, most of the plants (except fungi) synthesize their own food. Green plants absorb water and mineral elements from the soil through their root hairs, and also receive the carbon dioxide from the air and utilize them to produce carbohydrate in presence of sunlight. This chemical reaction takes place in the chlorophyll containing tissue of plant body. The process of formation of carbohydrate as food material in the protoplasm is known as photosynthesis. The carbohydrate later on is converted into protein and fat. This type of nutrition is known as autotrophic nutrition.

Animals cannot synthesize their own food within their body. So they depend directly or indirectly on plants for their food supply. In case of animals, the food matter is never stored directly in the protoplasm. Rather it involves a number of phases before it gets assimilated in the protoplasm. In the first phase, the solid food matter is taken within the body and this phenomenon is known as *ingestion*. In the second phase, the ingested complex food matter is broken down by enzymes into simpler soluble forms; this is known as *digestion*. In the third phase, the digested simpler materials diffuse from cell to cell and are carried to the different parts of the body. This phenomenon is called *absorption*. In the fourth phase, the absorbed simpler food materials are immediately utilized and stored in the protoplasm for future use. This is known as *assimilation*. The ultimate aim of nutrition is the assimilation of food matter into the protoplasm. All the food which is ingested, may not be digested or absorbed in the body. So undigested residual food is thrown out from the body. This process is known as *egestion*. This type of nutrition is known as *heterotrophic nutrition*.

[b] Respiration:

Respiration is a **katabolic process**. The process of gaseous exchange and energy release is known as respiration. During respiration, the oxygen enters into the body cell and oxidises the food substances specially the carbohydrates and fats. As a result of oxidation, energy is released with the production of carbon dioxide and water. The main aim of respiration is to release the kinetic energy from potential energy of food. This energy is utilised by the body during its various activities whereas the carbon dioxide and water are given out to the environment. In this process, the food materials stored in the body are broken down; so, respiration is regarded as the **destructive process of metabolism**. In the living organisms, respiration occurs throughout the life period.

[c] Secretion:

Secretion is a katabolic process. The cell produces certain new chemical substances during its katabolic process. Such useful substances of the body are called secretory products and the process is known as secretion. These secretory products take part in the various reactions of the living body. Enzymes and hormones are two important secretory products. Enzymes are very useful for digestion of food and other biological reactions. Hormones regulate the growth, development and behaviour of the organism. Hormones are regarded as a chemical messenger of the living body.

[d] Excretion:

The excretion is a katabolic process. In this process, various types of chemical substances are produced as by-products. These by-products are harmful to the body. These harmful substances are called excretory products. The excretory products are thrown out of the body along with some other such substances. The process by means of which these excretory substances are eliminated from the body is known as excretion. Excretory products are formed during oxidation of protoplasmic protein, carbohydrate and fat. Excretory products are mostly nitrogenous materials such as alkaloids, urea, uric acid, ammonia etc.

[5] GROWTH:

The permanent increase in size of a living organism is called *growth*. In living organisms the food after being absorbed is assimilated in the cells. Both the anabolic and katabolic types of chemical reactions are always going on in a cell. When anabolism exceeds katabolism, new organic substances are added to the protoplasm as a result cell increases in size and the individual body grows. In living body, growth takes place by the deposition of new materials in the protoplasm and this type of growth is known as *intussusception*. A non-living body, may grow in volume by simple deposition of identical matter on its outer surface and this type of gowth is known as *acretion*. As for example, a sugar crystal when placed in a concentrated sugar solution, increases its size due to deposition of new sugar particles on the outer surface of the original sugar crystal. So the sugar crystal increases its bulk by acretion.

[6] MOVEMENT AND LOCOMOTION:

When a living organism remains fixed to a place but its parts are moving, the phenomenon is known as movement. But when a living body moves from one place to another, the phenomenon is known as locomotion. Movement is associated with more or less to all plants and animals. Spontaneous protoplasmic movement is observed in all living bodies. This movement in a cell, helps to dristribute food and eliminate waste products. The higher plants are fixed in the soil, but their branches can move in response to external stimuli. So, movement is the characteristic feature of higher plants. But locomotion occurs in unicellular plants and in most of the animals. Some of the lower groups of plants move with the help of long whip-like structure known as flagella. Most of the unicellular animals move with the help of pseudopodia or flagella or cilia and these structures are regarded as the locomotory organs. In case of higher animals, specialised locomotory organs are present. With the help of specialised locomotory organs, they move from one place to another mainly in search of food and shelter. Vertebrate animals move from one place to another with the help of fins or wings or limbs. Fishes swim with their fins, birds fly with their wings and mammals are running

with limbs. Human beings walk with their two legs. So, movement and locomotion are the characteristics of living organisms.

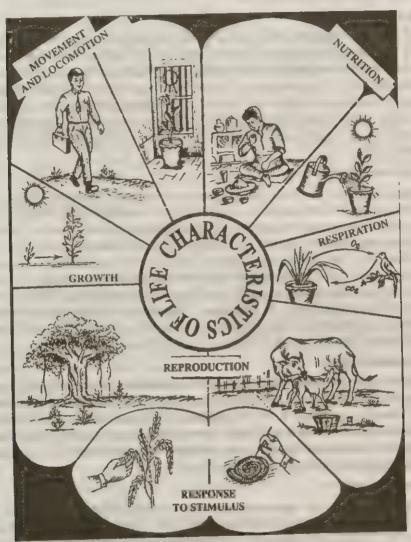


Fig. 1.1: Diagrammatic representation of the few characteristic features of life.

[7] RESPONSE TO STIMULUS:

All living organisms are capable of responding to certain changes in their immediate environment. This environment is regarded as both internal and external. Such changes which excite the living body are known as *stimuli*. The reaction of a stimulus is known as *response*.

Heat, light, touch, contact with acids and bases, enzymes, hormones are all regarded as common stimuli. If a living organism is excited by such a stimulus, the organism reacts and responds accordingly. As for example, leaves of a sensative plant droop-down to touch, many insects are attracted to light, a snail withdraws itself inside the

shell when it is touched. All living organisms respond to changes only to adjust themselves with the environment.

8 RHYTHMICITY:

In the living organism, all the vital activities are going on in a periodic or rhythmic fashion. In case of respiration, secretion, nutrition etc. their activities take place in a definite rhythm. The contraction and relaxation of heart and lungs are going on in a distinct rhythm. In living organisms, the activities of growth and reproduction are also rhythmic in nature. So in all of the functions, active phase is followed by a passive one. During the passive phase, protoplasm always regains energy for the next active phase, this goes on in a cyclic order. So the rhythm is one of the important characteristic features of life.

[9] REPRODUCTION:

Reproduction is one of the most important characteristic features of living body. The living organism after attaining maturity tends to multiply. The process by means of which a new generation comes into being is known as reproduction. The living organisms reproduce in various ways. Simpler types of organisms reproduce simply by extension of the growth and division. This is known as vegetative and asexual reproduction. In higher plants and animals the sexual reproduction requires two partners, here both the parents contribute to the formation of a new individual. Whatever may be the method of reproduction, the young ones after attaining the maturity resemble the parents. So continuity of life is maintained on the surface of the earth through reproduction. Reproduction is a triumph card in the hands of living beings.

[10] ADAPTATION:

All living organisms try to adjust with their particular environment through suitable changes in their organisation so that they can cope with the changes in the environment. This is known as *adaptation*. For this quality, the living organism can efficiently lead their lives in water or land or air till date. Some of the organism became extinct, because they failed to adjust with the changing condition of the environment. So adaptation is also an important feature of living organism.

[11] MUTABILITY:

Mutability is also an important characteristic feature of living organisms. In living body, genes are present in chromosomes of a cell. These genes are controlling the hereditary characters. Occasionally new combinations of characters appear suddenly in the offspring due to permanent change either in genes or in chromosomes. This is known as mutation and the power of living organism to mutate is regarded as mutability. This mutability helps in evolution of the living world. Such phenomenon is not seen in the non-living substances.

[12] EVOLUTION:

Life first originated on the earth surface in a very simple form. This simple form of life gradually changed and gave rise to the present form of various complex organisms through millions of years. This slow and gradual change of organism through successive generations is known as *evolution*. But many of the organisms, which failed to adapt to the changing environmental conditions, became extinct. Such evolution is not seen in the non-living world.

[13] LIFE CYCLE:

In a living organism, there is a definite life cycle. Duration of life cycle varies from organism to organism. After birth, the living organism takes food and gradually grows to adult stage. The adult organism reproduces and gives rise to offsprings. The offspring grows again to adult stage. This is known as *life cycle*. For instance, in life cycle of higher plants these stages are seed, seedling and adult and in insect, they are egg, larva, pupa and adult.

[14] SENESCENCE AND DEATH:

In living organisms, the life span is limited and birth and death are inevitable. The duration of life varies in different kinds of organisms. In the later period of life, the metabolic activities gradually gets reduced. This is known as *senescence* or old age. After this period, the activities of life totally disappear and death occurs.

1.2. Status of Biology

Ewo types of materials are observed on the earth. One type is non-living, such as soil, minerals, water, air etc. The other one is living material. The living materials are plants and animals. The earth becomes full of life due to their existence. Human being gradually developed their curiosity to know about the different aspects of living and non-living substances on the earth. Due to development of scientific attitude in man, many of the complex problems of living and non-living objects are gradually being solved. Naturally the question may arise what do we understand by the term 'Science'. In one word we can say that a systematic knowledge of any object is known as science. Science spreads into two important branches, such as Physical science and Biological science. Out of these two branches, the biological science becomes a very important branch of science. This branch deals with the plants and animals including the human being—all of them are treated as living organism.

The branch of science which deals with the living organisms about their nature, life processes, relationship with the environment, evolution etc. is known as biology

So biology is the science of life **Jean Baptiste Lamarck** (1744-1829), a French naturalist, first coined the term *Biology* in the year 1801. This is a Greek terminology (*Bios* = life, *logos* = knowledge).

The main aim of science is to enquire about the truth. This truth is enquired through systematic study of experiment, observation during experiment and analysis of the result only to come to correct deduction. On the basis of experiment, observation and deduction, a hypothesis is formed. Afterwards on conformity from all other sources, a hypothesis is accepted as a theory. The experimentations, observations and deductions about the structural and functional diversities of living organism are still being carried out. So this type of scientific analysis is the matter of all sciences including biology.

1.3. Biology: in ancient period

Between 8,000-10,000 years ago, ancient people of India worked out a scientific revolution of the highest order in relation to the conversion of wild grass into rice. They started cultivation of rice, wheat etc. by domestication of wild grass. As a result, a stable civilized society was formed. Subsequently they spent more time for

development of science. Thus, there was a great achievement of sciences particulalry in agriculture, veterinary science, fishery science and domestication of animals and plants in Indian subcontinent.

Ancient men of western world as well as in Indian subcontinent discovered medicinal properties of many plants. In India, we find references about the medicinal plant of 700-1000 in Susruta Samhita and Charaka Samhita.

In the ancient period in India, there was a surprising development of medical science. This development was done by many Indian physicians particularly by Aswinikumar, Dhanvantari, Susruta and Charaka. Dhanvantari was regarded as the *God of Medicine*. Susruta and Charaka classified animals and plants. But the classification was not fully scientific as in the modern days.

In short, we can say that there was tremendous development in applied branches of biology in India more than two thousand years ago.

In the western world, even during the Aristotle's time, biology did not develop as a scientific discipline.

From the early sixteenth century, scientists of western world worked in the different fields of science. Their scientific works laid the strong foundation for the emergence of contemporary biology.

The discovery and the formulation of a new concept is never solely the work of one scientist. It is rather a culmination of the efforts of many scientists and researchers. They have toiled to advance the frontiers of science through the years.

It is desirable for all students to have an understanding of science both current developments and the background in which the current developments have taken place. To obtain such an understanding it is necessary to read about the lives and achievements of the great scientists of the past and present.

In this book, authors present significant highlights in the lives of some great scientists and the record of their achievements in the field of biology.

We hope that there may be some, who will find inspiration to enter the field of biological science and make their own contributions to the welfare of mankind.

- SUSRUTA - [600 B.C]

Susruta was one of the earliest eminent Indian Ayurvedic physician, who was rational and most scientific in his approach. During the period of Susruta, the medical science developed in India along the same line of thought as that of modern western science.

The most important contributions of Susruta are given below:

- 1. He classified all substances into *Sthavara* (immobile) and *Jangama* (mobile). Immobile was regarded as plants and mobile into animals.
- 2. He classified plants into *Vanaspati* (fruit yielding non-flowering), *Vraksa* (fruit yielding flowering), *Virudha* (shrubs and creepers) and *Osadhi* (plants that die after ripening of fruits).
- 3. He not only classified the plants but also described the various parts of plants, such as ankura, mula, kanda, patra, puspa, phala etc.
- 4. Susruta also classified the animals into the following groups: Kulacara (herbivorous animals), Matsya (fishes), Janghala (wild herbivorous quadrupeds) like elephant, buffalo and Guhasaya (Carnivorous quadrupeds like tiger, lion).

5. The book, Susruta Samhita also mentioned some observations on both venomous and non-venomous snakes and leeches. Description of leeches was also mentioned in the book.

6. Susruta was one of the earliest scientist who studied human anatomy on dead

7. He himself carried out plastic surgery on human nose. Susruta performed surgery for the treatment of cataracts. He also used live leeches (non-poisonous) for preventing clotting of blood during operations. He also developed the process of anaesthesia and sterilization before undertaking the surgery proper. Hence, he is regarded as the 'Father of surgery'.

8. He also developed the concept that some diseases like diarrhoea and dysentery are water-borne, and preventing measures were recommended to drink boiled water

and milk and some medicine from barks of plants would be mixed in it.

----CHARAKA 1100 B.Cl

Charaka was also an eminent Indian Ayurvedic physician of ancient time. Charaka also wrote a book known as Charaka Samhita. His contributions in biology are given below:

- 1. Charaka mentioned near about 400 medicinal plants. He also mentioned the classification of animals. This classification was based on the food habits and habitats of animals. But the classification was not fully scientific from the modern point of view.
 - 2. He made for the first time the concept of digestion, metabolism and immunity.
- 3. Charaka mentioned that the body's normal functioning is going on due to proper balance among the three doshas, such as bile (pitta), phlegm (spit or kaph) and wind (vayu). When the balance among the three doshas in a human body gets disturbed then and then disease occurs. He prescribed the medicines for restoring the balance among the doshas, to make the human body normal.

4. He knew the factors which determined the sex of a child. So he had also the

fundamental knowledge about genetics.

5. Ayurveda (Ayu = life; veda = knowledge), the Indian system of medicine was developed by taking ideas from the doctrines of Charaka Samhita.

----ARISTOTLE----[384-322 B.C.]

Aristotle was born in 384 B.C. at Stagira, a small town in Greece. His father was a physician to the king of Macedonia. Under the influence of his father, Aristotle showed keen interest in natural science. At the age of seventeen, Aristotle was sent to Athens to attend the Academy of Plato. The great philosopher Plato recognised Aristole's genius. Aristotle was the most distinguished of Plato's pupils but there was profound differences in the thinking between the student and the master.

After the death of Plato in 347 B.C., Aristotle was expecting to become the head of the Academy. But his headship was denied and out of disappointment he left Athens.

In 342 B.C. Aristotle was invited by King Philip of Macedonia to become the tutor of young Alexander. Aristotle accepted the invitation and remained in Macedonia for seven years as tutor to Alexander, till he became the King. After that Aristotle left Macedonia and came back to Athens where he set up his own institution. Here he was attached for thirteen years and died in 322 B.C. Aristotle was a great philosopher as well as naturalist. He sought knowledge in diverse fields.

Contributions: Aristotle was interested in watching animals and their habits. He was a keen observer of nature and maintained notes of those observations. Some

important contributions of Aristotle are as follows:

- [1] Aristotle gave a good account of the breeding habits of cat fishes. Of the marine fishes, his accounts about the reproduction and development in *Torpedo* and Angler fish are perfectly correct.
 - [2] Aristotle gave a perfect description of the development of Octopus and Sepia.
- [3] Aristotle had a clear idea about the anatomy, physiology and embryology of the mammalian group, so he separated the group of mammals such as whale, porpoise and dolphin from the fishes.
- [4] Aristotle was the founder of classification of living things. His classifications remained virtually unchanged till the work of Linnaeus in the eighteenth century.
- [5] Aristotle did not believe in 'special creation' in evolutionary process. He believed that the higher grade of organisms developed from the lower grade of organisms. This idea of organic evolution guided biologists to the right direction.

____ANDREAS VESALIUS _____ [1514–1564]

Andreas Vesalius was born in Brussels (Belgium) on 31st December 1514. After his early training at Brussels and at the University of Louvain he went to Paris to study medicine. In deep depression, Vesalius returned to Louvain without the medical degree. He completed his medical studies at the University of Padua (Italy), where he was appointed as a professor of surgery and anatomy. First anatomy class of Vesalius was a real 'first' in medical history. He personally performed the complete dissection of the human body. He died in October, 1564.

Contributions: [1] He published a book known as 'De Humani Corporis Fabrica' (The structure of the human body). It is a masterpiece in the biological field. He described the bones and joints of human body with much accuracy. He was honoured as 'Father of Anatomy'. He was successful in describing and drawing the muscles of human body. [ii] He also described the differences between the skull of man and dog. [iii] Vesalius gave a fair description of the structure of human heart.

---WILLIAM HARVEY----

[1578-1657]

William Harvey was born at Folkstone, on the south coast of England in 1578. In 1588, the ten-year old William entered Kings School, Canterbury. William entered Cains College in Cambridge. He graduated in 1597. From Cambridge, he went to the famous institution at Padua in search of best medical instruction. Harvey received his medical degree in 1602. Then he returned to England to resume his studies at Cambridge University. In 1615, William was called to deliver a lecture on anatomy at the Royal College of Physicians in London.

Contributions: [i] The most important contribution of William Harvey is on circulation of blood. In 1628, 'Anatomical Exercise on the motion of the Heart and Blood' a concise monograph was published. He showed for the first time that the blood in the body moves in a circuit and the heart is the organ of reception and propulsion of blood.

[ii] Hurvey plunged into new research on the processes of reproduction and embryonic development of chick, deer and man. He also published a book 'Exercises on the Generation of Animals' in 1651.

[iii] He also worked on *comparative anatomy* and *development of insects*. The manuscripts and drawings of these works were destroyed during the civil strife in 1642.

| - - - - - MARCELLO MALPIGHI - - - - - - - - |

Marcello Malpighi was born in 1628 in a small town near Bologna in northern Italy. He was twenty-three years old when he entered medical school at the University of Bologna. Marcello Malpighi received his Doctor of Medicine in 1653 when he was twenty-five years old. In 1656, he was appointed as a professor of medicine at the University of Pisa. He was elected an honorary member of the Royal Society in 1668. He is recognized as the *founder of microscopic anatomy*.

Contributions: [i] Malpighi's greatest discovery was the presence of smaller

microscopic capillaries of blood vessel which had baffled Harvey.

[ii] While examining the fine structure of the lung of a frog, he saw for the first time the alveoli or air sacs.

[iii] He discovered the malpighian corpuscles of kidney and malpighian tubules of insects.

[iv] In 1669, he published a monograph 'The structure and metamorphosis of the Silkworm'. The monograph was the first of its kind in the history of Zoology.

[v] Malpighi also noted for the first time the stomata in the leaf epidermis. Many other observations were made in his thesis on 'Plant Anatomy' which is a milestone in the science of botany.

____ ANTON VAN LEEUWENHOEK _______ [1632–1723]

Anton van Leeuwenhoek was born in Delft, Holland, on October, 1632. He came from a respected family of brewers. When Anton van Leeuwenhoek's father died, his schooling came to an end at the age of sixteen. He left the town and came to Amsterdam where he was apprenticed as a clerk in a dry-goods store. At the age of twenty one, he left Amsterdam and returned to Delft where he opened his own dry-goods store. He spent all the spare time on microscopy. The Royal Society honoured this untutored Dutchman and he was elected as a Fellow of the Society in 1680.

Contributions: [i] Van Leeuwenhoek made 'simple microscopes' with his lenses

which were remarkably effective.

[ii] He first made drawings of bacteria in 1683.

[iii] He discovered free living Protozoa in fresh water ponds, such as Euglena viridis and several species of Ciliates.

[iv] He also gave accurate descriptions of the blood corpuscles of some invertebrates.

[v] He described the compound eyes of insects.

[vi] Leeuwenhoek gave the detailed accounts of muscles, teeth, skin and many others.

ROBERT HOOKE

[1635-1703]

Robert Hooke was born on September 18, 1635 on the Isle of Wight off the Southern coast of England. Robert Hooke was a sensitive and sickly child. The sudden death of his father when Robert was only thurteen years old was a tragic blow. Robert went to London and became an artist's apprentice. He was forced to quit his apprenticeship for health ground. Finally he was able to attend at Westminister school, where he proved to be a brilliant student. When he was eighteen, he entered Oxford University. While at Oxford, he met his teacher Robert Boyle, who was a brilliant chemist. Robert Boyle employed Hooke as a research and laboratory assistant in his laboratory. Subsequently he was appointed as the first Curator of Royal Society. Later Hooke was invited to become a member of the Royal Society.

Contributions: Robert Hooke was primarily a physical instrumenter but gave

some time in microscopic studies.

[i] He published a book 'Micrographia' in 1665. In this book, he described the minute structure of familiar plants and animals which he had observed with a microspope designed and constructed by him.

[ii] He coined the word 'cell'-the tiny box-like components of thin slices of cork. This term is now universally used for the unit structures which make up the tissues of

all organisms.

[iii] Hooke also described the radula of mollusc and the structure of the feathers.

CAROLUS LINNAEUS

[1707-1778]

Carolus Linnaeus was born in Rashult, Sweden in 1707. Linnaeus was fascinated by nature's wonders. In 1732, Linnaeus set out for Lapland, Sweden's most northern province, to make a first-hand study of its flowers and its natural resources. He travelled thousands of miles and brought back more than a hundred specimens of new species. Linnaeus then went to Holland to study medicine for three years. He divided his time between his medical courses and his observation of Holland's rich plant life. He obtained the degree of doctor of medicine in 1735. After returning to Sweden, he practiced medicine successfully but all the while his heart was with his flowers. Subsequently Linnaeus was appointed Professor of *Natural History at Upsala*, Sweden.

Contributions: [i] Carolus Linnaeus introduced the system of 'Binomial

nomenclature' of plants and animals.

[ii] Tenth edition of his famous book, 'Systema Naturae' was published in 1758.

[iii] He also published other books, such as 'Genera Plantarum', 'Bibliotheca Botanica' etc.

Lamarck was born in 1744 at Bazantin, France. He had given up his theological studies to join the French army. In the army barrack, a fellow officer playfully lifted him by the head, seriously injuring Lamarck's lymph glands. This made him unfit for military life and he left the military service. Lamarck went to Paris to study medicine supporting himself with clerical work. Lamarck caught the love of nature and a special interest in botany and so abandoned the thoughts of a medical career. He threw himself into an enthusiastic study of plant life. Later on he was appointed as the custodian of the herbarium of Louis' garden. Under Lamarck's supervision, Louis' garden became an international show place. The revolutionary government appointed him at the Museum of Natural History as a professor of zoology. Lamarck concentrated on teaching about insects, worms and microscopic animals. In his later years, he became blind. Despite his hardships, he was dedicated to the discovery of the truth.

Contributions: [i] Lamarck collected enough data over a period of ten years to publish 'Flora of France' (Flore Francaise).

[ii] Lamarck first coined the word 'biology'.

[iii] He tried to classify animal kingdom and he was the first man, who distinguished Vetebrates from the Invertebrates.

[iv] Lamarck's theory of acquired characteristics, as explained in his 'Philosophie Zoologique', was published in 1809.

_____GEORGES LEOPOLD CUVIER______

Cuvier was born near Belfort, France in 1769. Cuvier's mother dedicated herself to the task of educating him. Mother provided him with books on natural history. He went off to spend four years at the University of Stuttgart, where he amazed the faculty with his encyclopedic knowledge. In 1795, Cuvier was appointed as an assistant to the professor of anatomy at the Museum of Natural History in Paris. In 1796, Cuvier presented his first important paper to the French Academy of Science. He became a professor at the renowed Jardin des Plantes; then secretary of the Institute de France. In 1808, Napoleon appointed Cuvier to the Council of the Imperial University, charging him to examine opportunities for higher education in France. In 1818, he was elected a member of the French Academy and in the following year the government selected him to head its Committee. He was appointed as President of the Council of State.

Contributions: [i] Cuvier was the first to identify the extinct bird-like reptile. He also studied the fossils of elephants and mammals. It was because of his efforts that palaeontology was established as a separate science.

[ii] He believed in fixity of species and that there was no evolution. He believed that vast number species had appeared on earth at different periods through *catastrophes*. These inferences are not correct.

[iii] In 1828, he published a book known as 'Natural History of Fish'. The book contained descriptions of more than five thousand different species.

---CHARLES DARWIN--

[1809-1882]

Charles Darwin was born in 1809 in Shrewsbery, England. His father was a successful and wealthy physician. His grandfather Dr. Erasmus Darwin was well-known as a doctor, a naturalist and an author. His father Robert wished him to follow the family profession of medicine. So Charles, was sent to the Edinburgh University in 1825 to study medicine. But Charles was less interested in medicine. He made several expeditions along the shores of England to study marine life. Then he was sent to Christ's College to become a clergyman. At twenty-two, Charles had a theological degree. At that time, he got an offer to go as naturalist on the voyage of the H.M.S. Beagle. The H.M.S. Beagle sailed in 1831 under captain Fitzroy. The Beagle was to survey the South American coastline. The first port of the Beagle was on the east coast of South America, in Brazil. From Brazil, the Beagle sailed to the West coast of South America. Everywhere Darwin had collected specimens and recorded his observations. After surveying many coasts and observing strange forms of plant and animal life, the ship dropped anchor at the Galapagos Islands, some five hundred miles west of South America. It was probably among these islands that Darwin first crystallized his idea of evolution. The voyage ended in 1835. In 1838, he was elected secretary of the Geological Society.

Contributions: [i] In November 1859, Darwin published a book 'The Origin of Species by means of Natural Selection' where he set forth his theory of evolution through natural selection. This is a monumental work on evolution.

[ii] Darwin also postulated a theory of 'The Descent of Man' in 1871.

[iii] He also published 'Variation of Animals and Plants under Domestication'.

- GREGOR JOHANN MENDEL -[1822-1884]

Gregor Mendel was born in July, 1822 at Heinzendorf, then part of Austria, now a part of Czech Republic. His father Anton, was a poor peasant but managed to send Gregor Mendel to the school. In 1843, he took admission in the Augustinian monastery at Brunn, a center of learning of philosophy, mathematics, music and science. In 1847, he was ordained as a priest.. He subsequently began to serve as a teacher of mathematics in the local gymnasium at Brunn. Mendel was sent to the University of Vienna for two years to study mathematics, physics and the natural sciences. He continued to teach natural science in the Brunn high school. In 1856, Mendel began his historic eight years long experimentation with pea plants in a small garden of the monastery at Brunn.

Contributions: Gregor Johann Mendel worked patiently and carefully, planting many varieties of peas in his monastery garden. After careful scientific cultivation, observation and analysis, he published his findings in the proceedings of the Natural History Society of Brunn in 1866.

Mendel deduced two important laws of heredity from his experiments. The laws of Mendel laid the foundation of modern genetics. Hence he is now regarded as the 'Father of Genetics'.

__LOUIS PASTEUR____

[1822-1895]

Louis Pasteur was born in the village of Dole in the eastern part of France in December 27, 1822. Soon after Louis' birth, the family moved to Arbois, in the heart of the grape country. At the age of fifteen he devoted himself to potrait painting. Many of his paintings have been preserved and hung in the Pasteur Institute in Paris. Louis' chief interests were mathematics, physics and chemistry. He successfully passed the practical classroom teaching test in physics and chemistry. However, when he received his degree, he turned to research instead of teaching. In 1848, he was assigned to teach elementary physics at a secondary school. A year later, Louis was appointed as a professor of chemistry at the University of Strasbourg. His early years as a young scientist were spent in studying the subject of crystal formation. News of his achievement resulted in offers from larger universities, and he moved to Lille. There he developed interest in microbes, and he worked in the field of microbiology for the rest of his life. He is now famous for his discoveries in this field.

Contributions: [i] Pasteur proved that fermentation is caused by living organisms

e.g. yeasts and bacteria.

[ii] The method of sterilization or germ killing was first introduced by Pasteur and the process which was named pasteurazation in his honour, is now the standard procedure in processing milk and other foods undergoing fermentation.

[iii] He saved the silk industry of France by discovering the causative organism of

pebrine disease of silkworm.

[iv] He discovered the vaccine against Anthrax bacillus of cattles.

[v] Pasteur also discovered the remedy of hydrophobia in man.

IVAN PETROVICH PAVLOV [1849-1936]

Ivan Pavlov, the son of village priest was born on September 14, 1849, in the small town Ryazan in central Russia. In 1870, Pavlov entered the St. Petersburg University, and completed his degree in Natural Science in 1875. In the same year, he joined the Military Medical Academy as a three year student and received his degree of *Doctor of Medicine* in 1879. Pavlov devoted his time to *physiological research* at a clinic in St. Petersburg. At the age of forty-one he was appointed as a Professor at the Medical Academy and a year later, he was placed in-charge of the newly established physiological laboratory at the St. Petersburg Institute of Experimental Medicine. In 1904, Pavlov was awarded Nobel Prize for his work on Physiology of Digestion. Pavlov became the first Russian to receive a Nobel Prize. He was honoured by Lenin.

Contributions: [i] In his experiments on the digestive system, Pavlov devised an operation of abdominal fistula through which gastric secretion could be collected for physiological studies.

[ii] Pavlov discovered enterokinase, which activates trypsinogen.
 [iii] He noted the augmentary effect of sympathetic nerve supplying the heart.
 Subsequently Pavlov explained the influence on differnt visceral organs.

[iv] Pavlov performed famous experiments on **conditioned reflex** of digestive juice secretion and he clearly distinguished it from unconditioned reflexes.

△THOMAS HUNT MORGAN

[1866-1945]

T.H. Morgan was born in 1866 in Lexington at Kentucky. He completed his undergraduate studies at the Kentucky college and entered John Hopkin's University in 1886 to study biology. He received his doctorate degree in 1890. After receiving doctorate degree, he came to the Marine Biological Station at Naples, Italy. Here he worked the biological problems of development and regeneration. When his post-doctoral fellowship grant expired at the end of one year, he returned to America. In 1891, he joined the biology faculty as an Associate professor at Bryn Mawr and stayed there upto 1904. Then he joined as a professor in experimental zoology at Columbia University. In 1928, Morgan joined the California Institute of Technology and organised the Division of Biology, where he remained till his death. Morgan received the Nobel Prize in Medicine in 1933.

Contributions: [i] Morgan made contributions on regeneration and development of marine lives at the beginning of his research career.

- [ii] Subsequently his experimental material was *Drosophila* (fruit fly) and he studied on heredity and variation. Introduction of *Drosophila* as a laboratory material accelerated the investigations in genetics.
- [iii] Morgan and his associates published series of books on genetics. 'The Mechanism of Mendelian Heredity' was published in 1915. This book is regarded as the most important milestone in the science of genetics.
- [iv] The principle of sex-linkage postulated by Morgan was published in a book 'Sex linked inheritance in *Drosophila*' in 1916.
- [v] In 1926, Morgan synthesized all the knowledge on the hereditary material in his classical work, 'The Theory of the Gene'. This is another significant contribution which has laid the foundation of genetic research.

_ALEXANDER FLEMING _ _ -

[1881-1955]

Alexander Fleming was born at Lochfield farm in South-western Scotland on August 6, 1881. His father died when he was only seven. He was able to complete high school; then he was forced to leave education for economic reasons. When he was sixteen, he obtained a job in a shiping company. In 1901, he received a share in a legacy which enabled him to continue his education. He decided to study medicine. Fleming was a student at St. Mary's Medical School. He was also a member of the rifle team, the swimming team and the water polo team and even showed some ability in painting. Fleming graduated from St. Mary's Medical School in 1906 at the age of twenty five. Professor Almroth Wright asked Alexander Fleming to join him in bacteriological research. In 1928, Alexander Fleming was appointed as a professor of bacteriology at the University of London. But he continued his research in the laboratory at St. Mary's Hospital for a more potent germ killer. In 1945, Alexander Fleming's achievement was recognized by a Nobel Prize in Medicine.

Contributions: [i] Alexander Fleming reported his findings to the Royal Society of London in a paper entitled 'On a Remarkable Bacteriolytic Element Found in

Tissues and Secretions'. Lysozyme was a natural enzyme which would destroy harmful bacteria.

[11] Fleming discovered that the chemical substance, called **penicillin** produced by the mold (*Penicillium*) could prevent bacteria from growing, could kill bacteria and could dissolve bacteria in the body without injuring leucocytes of the blood.

As Therapeutic agent: In 1938, two British chemists, Howard Florey and E.B. Chain began to investigate the possibility of *isolating penicillin* in its pure form. In 1941, they succeeded and penicillin was used successfully in clinical tests on human beings.

Sir Alexander Fleming opened up a new field of research on the antibiotics. Subsequently in the United States, Dr. Selman Waksman of Rutgers University discovered *Streptomycin*.

1890–1967]

H. J. Muller was born in New York City on December 21, 1890. He was attending Morris High School at New York City. His superior achievement in High School resulted in a scholarship to Columbia University in 1907. Muller received his bachelor's degree in 1910. He received his doctorate degree from the Columbia University in 1916. In 1920, Muller became an Associate Professor of Zoology at the University of Texas. He received a Guggenhein research grant in 1932, to pursue his studies in the Berlin laboratory. A year later, Muller accepted an invitation to become senior geneticist at the Institute of Genetics of the Russian academy of Science at Moscow. He remained there for four years. Muller worked at the Institute of Animal Genetics at the University of Edinburgh just before the second world war. In 1940, he returned to the United states to teach and continue his research at Amherst College. In 1945, he was appointed Professor of Zoology at Indiana University and he was busy there with his research work on genetics. Muller was awarded Nobel Prize in Medicine in 1946 for his discovery of the production of mutations by X-ray irradiation.

Contributions: [i] Muller's first paper, reported his discovery of a new gene for bent wings on the tiny fourth chromosome of the *Drosophila* in 1919.

[ii] Muller collaborated with Morgan in the writing of an epochal book 'The Mechanism of Mendelian Heredity'.

[iii] In 1927, Muller published his work on 'The Artificial Transmutation of the Gene'. Muller concluded that the radiation exposure produces mutations similar to those occurring spontaneously in nature. He also concluded that high dosages of radiation increases mutation frequencies to many times the frequency level of spontaneous mutations.

1.4. Biology and its relation to other Sciences

Science is diversified into different main branches. At the primary stage of science, each branch deals with exclusively its own objects, and new discoveries and inventions are added day by day to each branch. In this way each branch of science is expanded. Due to advancement of sciences, the different branches are coming closer and are establishing inter-relationship amongst themselves. For example, many concepts of physical sciences, particularly the laws of physics and chemistry are used to solve the

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1.5. Scope of Biology

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mysteries of biology. As a result, many new sub-branches have been developed. Important sub-branches which have relationship with the biology are discussed below.

[1] Bio-physics:

In collaboration of physics with biology, a new branch of science has developed which is known as bio-physics. Physiological processes like diffusion, osmosis etc. occurring in the living body can be explained with the help of the principles of physical science. Various phenomena like shape, locomotion, circulation of living organisms are guided by the laws of physical science. Microscope is a very important instrument for biologists and the further development of this instrument to a modern powerful one is the contribution of physicist. By its use, biologist discovered many new structural concepts of the living body. This modern branch of science is now gradually developing by the untiring efforts of both the physicist as well as biologist.

[2] Bio-chemistry:

A complementary branch of biology is formed with the help of chemistry and this new branch of science is called *bio-chemistry*. Chemical combinations and their reactions in the protoplasm are guided by the principles of chemistry. Synthesis and functions of various complex substances like enzyme, hormone etc. can be explained from the knowledge of chemistry. So the knowledge of chemistry is essential for better understanding of the life processes in living organism.

[3] Bio-metrics:

Bio-metrics, a new complementary branch of biology has been developed from the knowledge of mathematics. Many principles of mathematics are being helpful to the biologists in explaining many problems of biology. Problems of growth, size of population and other various concepts of biology can be explained with the principles of mathematics.

[4] Bio-engineering:

A modern branch of science developed by co-operation of engineering and biology, is known as *bio-engineering*. Based on the knowledge of engineering many problems of biology such as structure and working of limbs etc. can be explained.

[5] Cybernetics:

This branch of science has been formed in collaboration of biology with that of technology. The cyber world provides the information regarding gene and protein sequence that can be utilized by genetic engineers in developing transgenic organisms.

[6] Bionics:

This new branch is also developed in collaboration of electronics with biology. This principle leads to the development of DNA based chips, which will produce computers that can think.

[7] Space-biology (Exobiology):

Space-biology is a modern branch of science which has been developed in collaboration with biology. This branch is very useful in the field of space-research. It deals with the behaviour of living organism in outer space, origin of extraterrestrial form of lives etc.

[8] Other branches:

In addition to the above, the following branches of sciencies are also helpful for thorough understanding of various life processes of plants and animals—such as geology, palaeontology, anthropology, bio-geography etc.

Therefore, it is evident from the above facts that the modern biology establishes correlation between biology and other branches of sciences. The knowledge of other branches of sciences are essential for better and clear understanding about all aspects of plants and animals. In one word the knowledge we can say that other branches of sciences supplements of biology.

1.5. Scope of Biology

Scope of Biology was limited even before hundred fifty or two hundred years ago. At that time, it was more or less limited within the jurisdiction of life processes, distribution and nomenclature of plants and animals. Gradually this science spread into different new horizons. As a result, this science is now diversified into different branches like cytology, adaptation, evolution, heredity, ecology, conservation etc. By the untiring efforts of the biologists, all the branches of biology are developing at a fast rate. For this progress, biological science contributes in the development of agriculture, medicine, horticulture, animal husbandry, pharmacognosy etc. So human society is now depending on biology for food, clothes, health etc. A few facts about the scope of biology in relation to human welfare are given below.

[1] In food production:

Modern human society does not depend on hunting, fishing and collecting wild fruits from forests like primitive man. Application of advanced knowledge of biological science has resulted in the development of agriculture, animal husbandry and fishery which are applied branches of the basic biological science. Human being is trying to solve the food problem of the growing population through the applied branches. How the application of the principles of biological science helps in enhancing our food production, is discussed below.

[i] High yield variety of seeds: Based on the knowledge of genetics, hybridization of crop plants has been done. As a result, more productive varieties of crop seeds such as rice, wheat, sugarcane, pulses etc. are now being discovered. Then those productive and disease resistant seeds are distributed throughout the country, so that cultivators can utilise those high yielding varieties of seeds and produce more crops at a time.

[ii] Increase in number and size of fruits: It is now possible to increase in number and size of the better variety of fruits such as grapes, orange, apple, pineapple etc. by application of the modern knowledge of biological science.

[iii] Production of Seedless fruits: Before pollination, a plant hormone auxin is applied in the female parts of flower and as a result the ovary increases rapidly without formation of seeds. Thus, the seedless fruits are produced and the cultivation of fruits increases rapidly.

[iv] Production of improved variety of poultry birds & other animals: Human beings have domesticated many varieties of birds and other animals for the welfare of the society. Domestication of birds and animals helps us in steady supply of milk, meat, egg etc. At the advent of modern ages artifical insemination of cattles and cross breeding of fowl, duck etc. have been carried out with a view to increase the milk or egg production. These experimental breedings with the help of modern biological knowledge have helped us in the production of improved varieties of birds and domesticated animals. As a result, milk, egg etc. are produced in greater amount and

numbers. For scientific rearing of cattles, foul and duck etc., dairy farm and poultry farm have been developed.

[v] In Fishery: High yielding better hybrid varieties of edible fishes are developed by application of modern techniques of biology. The hybrid varieties of small fry are distributed to fisherman and they are imparted with scientific instructions for rearing them. The techniques of *induced breeding* and the *composite fish culture* help us to produce more edible fishes.

[2] In control of Crop pests:

Earlier, large percentage of crops in the field were mainly damaged by fungi, insects and rats which are regarded as crop pests. Modern biology helps us to know the life history of those harmful organisms as well as the crops; this knowledge has helped us to protect the crops from the harmful organisms. As for example, the chemical substances like the *insecticides*, *rodenticides*, *fungicides* and *fumigants* are used to protect the crops against the pests. Recenty, biological knowledge also helps us to control the pests by another living agencies *i.e.* biological methods of pest control has been introduced. So we can say, by taking adequate scientific measures, pests and plant diseases can be controlled now a days.

[3] In production of Clothes:

Primitive men used bark and leaves of plants to cover their bodies. With the advancement of science, man has acquired techniques of weaving from the natural fibres of cotton. Now, by utilising the knowledge of biology, men are producing the high yielding variety of cotton by hybridization.

In addition to cotton fibre, silk and wool are also obtained from silk-moth and sheep. Better kinds of silk-moth and sheep are experimentally bred with a view to increase the rigidity, fineness and other qualities of fibres.

So, knowledge of biology is essential for the improvement of silk, wool and cotton industries and many people are engaged in these industries today.

[4] In Medicine:

Basic knowledge of biology is essential to understand the medical science. Experimentation in biological field helps us to know that many of the diseases are caused by microbes, worms, fungi etc. Only with the perfect knowledge about those harmful agents, prevention against the diseases is possible. Serum, vaccine and hormones which are used in many of the diseases of man, are produced from animal body. Scientists like Louis Pasteur, Ronald Ross discovered microbes of many of the diseases. As a result, diseases are now cured or prevented by application of medicines. A number of medicines are the products of plants and animals. Those products which are prepared or discovered in the laboratory are tested in the guineapig, white rat, rabbit etc. If the result after experimentation on animal body gives positive response, only then these medicines can be applied to man in curing the human diseases. Quinine, penicillin, belladonna, nux vomica. kalmegh like many of the medicines, are the products of medicinal plants. Primary knowledge and the progress of the surgery largely depend on the sacrifice of many animals. In this way, the medical science advances with the help of biological science.

[5] In Agriculture:

At the dawn of human civilization, man started to cultivate the plants for agricultural production. Since then, agricultural production gradually increased by the application of modern tools and techniques. In modern days the human population has increased, so demand of food has also increased. To fulfill this demand, all efforts are made to increase the agricultural production. This is done by expansion of land for cultivation, increase of irrigation facilities, intensive cultivation with improved varieties of seed, rotation of crop with more than one crop in cultivated area and proper use of fertilizers. As a result, the total agricultural production has increased. In the increase of agricultural production, there is a great role of biology.

Improvement of crops in quality and quantity has been done by hybridization tenchnique. By this technique, new hybrid varieties of high yielding crops, particularly rice and wheat are developed. These are also resistant to rust diseases. New breeds are also developed by mutation method. Micropropagation method is also applied for improvement of crop. In the application of all these methods, biological knowledge is

essential.

[6] In different industries:

The progress of many industries such as jute industry, tea industry, lac culture, apiculture etc. are largely dependent on the contribution of the biological sciences. Few facts are illustrated below.

[i] Jute Industry: High yielding better variety of jute seed is produced by cross-breeding of the different types of jute plant. These seeds are cultivated to produce large amount of jute which is the raw material of the industry. So this industry depends on the steady supply of the good quality of jute fibre. This is possible only by taking adequate scientific measures.

[ii] Tea industry: The knowledge of biology, specially botany helps to develop this industry. The knowledge of botany is applied on the cross breeding of the different varieties of tea plant. As a result, the healthy leaf bearing plants are produced. So the

quantity as well as the quality of tea both are increased.

[iii] Lac culture: Lac insect secretes a resinous substance on the twigs of some specific plants. The dried resinous substance is known as lac. Life history of the lac insect and its enemies have been discovered by the untiring efforts of the biologists. As a result, the scientific rearing has started. In the eastern part of the India specially in Bihar, the lac culture is expanding in a tremendous dimension. Now by taking adequate scientific measures in rearing, the production of lac is increased. This is used commercially in different ways, such as in preparation of gramaphone disc, in varnishing of wooden furnitures, etc.

[iv] Apiculture: In nature, the honey bees construct their hives either on the branches of trees or in other places. From the dawn of civilization, the human beings are collecting honey and wax from the hives of honey bees. Even today men are collecting those materials from the dense forest of Sunderban and other places. By the sincere reséar work of the biologists, the life history of honey bees, their behaviour and even that their enemies have been discovered. As a result, the scientific rearing has been started in the last century. Now for the rearing of honey bees, the movable wooden box has

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been invented. So instead of depending on nature, man is now rearing the honey bees in the wooden box which is being placed in the flowering garden. Human being collects the honey from the hive of the wooden box without damaging the hive. With the help of scientific measures the production of honey and wax has increased manyfold. The honey is used by many persons even the diabetic ones can use it as food. In Ayurvedic method of treatment, the honey is used as medium in many of the medicines. Wax of the hive is used in the preparation of cosmetics, creams, candles etc.

[7] In conservation of forests and wild animals:

Forests and wild animals are very important resources of a country. From those resources man derives timber, fur etc. and these are very useful materials of the human society. In natural condition of a forest, both plants and animals exist in a perfect harmony. If plants are destroyed injudiciously in a forest, the balance of the natural condition will be hampered and the climatic condition of the surrounding areas will be changed. So also if the wild animals are destroyed indiscriminately, then the balance of the nature will be adversely affected. So for the sake of human being, the balance of the nature is to be maintained. Proper and judicious conservation of plants and animals in a forest requires fundamental knowledge of the principles of biology.

[8] In prevention of Pollution:

With the advancement of modern technology, the human beings are developing varieties of big industries and these industries are growing specially in advance countries. The waste products of those industries are thrown in the environment and the environment is being polluted. Due to injudicious use of insecticides in the cultivating field, the water and other environmental components are also polluted. So the man himself is polluting his own environment. Every level of human societies is now facing acute problems of environmental pollution. Though consciousness of the people has developed to some extent about the environmental science, still it requires more knowledge about the biological science. So, the help of the biologist is essential to solve the problem properly.

[9] In the maintenance of public health:

Public health is concerned with the activities that help to maintain the health of human beings inhabiting in both rural and urban areas. The activities in relation to public health services are organised by the Government as well as other public organisations. In order to get a service in these organisations, fundamental concept about biological science is essential.

We know that in our country generally the waste materials are thrown in ditches, tanks, rivers etc. As a result, these garbage dump areas become the breeding places of many harmful insects and also contain harmful germs. Bad smell is also coming out from these places. If these places are not treated properly, various types of diseases will occur and cause hazards to the public health. So these dumped waste materials are to be treated properly by some bacteria and other chemicals. As a result, simple organic compounds are formed and these are used as fertilizer in the agricultural field.

People specially in rural areas collect their drinking water from wells, ponds, lakes, reservoirs etc. These places are generally contaminated by harmful bacteria and other

microbes. As a result, they suffer from cholera, typhoid, jaundice etc. So it is necessary for the civic authorities to supply germ-free water to the people of rural as well as urban areas.

Various programmes are to be arranged by Government and voluntary organisations about public health and hygiene through charts and models to educate the people about their personal health. Trained organisers with biological knowledge will explain the people about the utility of vaccination, bad effects of contaminated food, beneficial effect of cleaning the insect breeding places etc.

[10] In control of population explosion:

The knowledge of biology helps the medical science to control the death rate of new born babies in one hand but on the other hand creates a new problem on human society, the problem of over population. The population explosion can be checked if the biological knowledge about the reproductive as well as hormonal processes are utilized so that existing rate of child birth of human being will be reduced. The knowledge of biology also helps us to have a clear idea about the functions of the different systems in our body. So, a thorough knowledge about the reproductive physiology will help the future parents to have their family size according to the need of their social structure.

To control the population explosion, family planning programmes have been introduced in India as well as in other developing countries. Programmes are-

[i] Oral contraceptive: use of oral contraceptive in female will check ovulation; consequently child birth will be reduced. As a result, the population growth will be in normal range.

[ii] Safe period: Chance of fertilization will be reduced if the couple follows the

'Safe period' in the menstrual cycle.

[iii] Surgical: Surgical intervention such as vasectomy, tubectomy and termination of early pregnancy will control the birth rate and consequently population growth will be checked.

[11] In Control of flood and soil erosion:

Flood in our country is a common phenomenon occurring every year in some or other places. This natural catastrophy makes a great loss of soil. As a result, many plants and animals are destroyed and the ecosystem is disturbed. Erosion of soil is affected mainly by deforestation and rain. Loss of fertility from top soil is gradually increased by flood and other natural calamities. So, control of flood and soil erosion is necessary for the benefit of all organisms including human beings. It has been noticed that water conservation is closely related with aforestation and soil conservation. Flood can be controlled by erection of dams which is to be constructed in consultation with the environmental scientists on different rivers to collect and store a huge amount of water. The soil erosion on the surface area is prevented by plantation of special type of grass which will bind soil to prevent soil erosion. In sea side, soil erosion by sea waves can be checked by plantation of sand binder trees like *Cassurina* etc. There is a great role of biology in control of flood and soil erosion.

[12] In search of fuels:

Coal and mineral oil are the two important substances of modern industrial civilization. In the geological strata coal is produced from the plant body and mineral oil is produced both from the plant as well as animal body through natural processes. Pollen grains of primitive flowers and foramina group of unicellular animals are preserved in the geological layer as fossils. During oil exploration, those fossils give a positive indication about the availability of oil in the sediment. So, knowledge of biology is also important in the exploration of natural fuels.

[13] In improvement of human race:

Many of the diseases in man are caused by genetic defects. These diseases are inherited from parents to offspring. Colour blindness, haemophilia, alkaptonuria etc. appear in the human body due to defect in chromosomes and genes. These diseases are transferred from one generation to next generation following the principles of heredity. These diseases can be avoided if they take advice from a specialised doctor before the marriage so that there will be no defective and abnormal children. We can improve the human race by eliminating these types of congenital defects and better race can be developed, this is known as eugenics. So, in the improvement of human race, the knowledge of the principles of genetics are essential.

[14] In space research:

Another very important contribution of biological science is in the field of space research. During exploration of the planet, cosmonauts keep the green alga *Chlorella* in the space craft, they use this *Chlorella* as a food material. In addition to this, *Chlorella* uses the CO_2 which is being released by the consmonauts during respiration inside the space craft and synthesise its own food. Thus, *Chlorella* remove the poisonous CO_2 and release O_2 as a by-product during the photosynthesis. This O_2 is utilized by the cosmonauts during breathing. In this way, the green alga helps in the space travel.

[15] In human recreation:

In addition to the economic and other necessities of life, biology is influencing the human society to understand the asthetic value of beautiful neighbours about the plants and animals. Varieties of colour and smell of flowers give pleasure to the human beings. They act as a source of inspiration to the poet, artists and musicians. Colouration of birds and their sweet song inspire the intellectual persons. Man has created Zoological garden, parks, gardens with decorative plants etc. for their own recreation. For the maintenance of the gardens trained persons are needed. Every cultured man must have a knowledge of biological science.

1.6. Importance of Biological Sciences in this millennium

Biology becomes more important due to its new and new achievements. This branch of science is now the most demanding of all sciences because of its manifold importance in human society. It influences our daily lives and also the future. Biology can help in maintaining and increasing our treasures of medicinal plants in this millennium. It will help more and more to understand how organisms interact with nature and also the

significance of maintaining the bio-diversity. Gradually we are coming to know that many of the diseases of human beings are running generation to generation, which are due to genetic disorders. We can be able to eradicate these hereditary diseases in coming years as our knowledge and understanding of genetics are rapidly expanding. Genetics will also be more important in detecting crime and disputed paternity correctly by DNA finger-printing. In the coming years, scientists will be able to produce genetically modified improved variety of crops. Biologists successfully produce cloned animals and plants, though in case of human cloning we must be very cautious. Because inspite of being beneficial to some extent, such as cloning can provide a child for an infertile couple or replace a child, who is dying or dead; it can create many problems such as lineage and kinship or legal issues etc.

In this millennium, biological science is very important in the different branches of science such as biotechnology, bioinformatics, bio-medical engineering, environmental management, genetic engineering, forensic science etc.

1. Biotechnology: Technical manipulation of living organisms. Biotechnology helps to produce genetically modified improved variety of crops and successfully cloned animals and plants.

2. Bioinformatics: Scientists help in systematic development and application of

computing systems in biological processes.

3. Biomedical Engineering (bioengineering): Scientists are engaged in the better production of spare parts for human beings for external use and also for implantation, such as artificial limbs, machines for artificial respiration etc.

- 4. Environmental Management: Scientists are keenly observing the environment or nature and they are finding out the solutions for the problems of environment and thereby help in the conservation of biodiversity. Thus, they maintain the balance of nature.
- 5. Genetic Engineering: Scientists are extracting selected genes from an organism or selected genes are synthesized and then inserting those genes to another organism with the help of a vector (plasmid), as a result organism develops with a new combination of genes. Here bad genes are replaced by good genes and hereditary diseases can be rectified by this process.

6. Forensic Science: Here the scientific knowledge about DNA finger prints, blood

typing etc. is applied to deal with criminal activities, civil and criminal law.

1.7. Different Branches of Biology

Biology is mainly divided into two major branches, such as botany and zoology. The branch of science which deals with plants is known as botany (Botane \equiv plant) and the branch which deals with animals is known as zoology (Zoon \equiv animal, logos \equiv knowledge). Both the botany and zoology of biological science are developing into pure and applied branches. Theories and concepts are in the domain of pure branch and the application of those theories for the human welfare are dealt in the applied branches. Different branches of biology both pure and applied are given below.

PURE BRANCHES OF BIOLOGY:

[1] Morphology (Greek-GK, $morphe \equiv \text{shape}$, $logos \equiv \text{study}$):

The branch which deals with the shape and external structures of living organisms, is known as morphology.

[2] Anatomy (Gk. ana = above, temnin = dissection):

The branch which deals with the gross structure of the internal organs, is known as anatomy.

[3] Histology (Gk. histos ≡ tissue, logos ≡ study):

This branch deals with the structure and composition of tissues.

[4] Cytology (Gk. kytos = hollow, logos = study):

The study of the structure and function of the cells is known as cytology.

[5] Physiology (Gk. physis = nature, logos = study):

The branch which deals with the functional activities of living body is known as physiology.

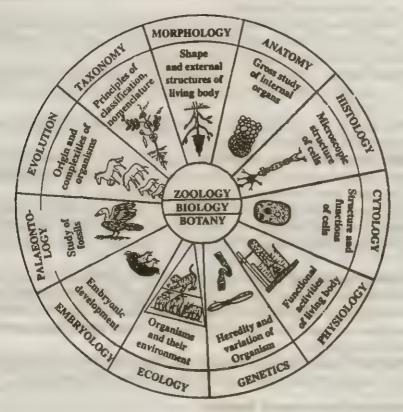


Fig. 1.2: Different branches of biology and their relationship.

[6] Ecology (Gk. oikos = house, logos = study):

The study of the relationship between organisms and their environment.

[7] Embryology (Gk. $em \equiv$ inside, $bryo \equiv$ to become swollen, $logos \equiv$ study): The study of the formation and development of embryo.

[8] Genetics (Gk. genesis = origin):

The branch of biology which deals with the heredity and variation of living organism, is known as genetics.

[9] Palaeontology (Gk. palaios = ancient, onto = existence, logos = study):

This branch deals with the principles of formation of fossils, its time scale and evaluation of fossils.

[10] Taxonomy (Gk. taxis = arragement, nomos = principles):

This branch of biology deals with the principles of classification of organisms and their nomenclature.

[11] Pathology (Gk, pathos = suffering, logos = study):

This branch deals with the diseases of living organisms.

[12] Evolution (Latin \equiv L., $e \equiv$ outside, $volvo \equiv$ develop):

The branch which deals with the origin and gradual complexities of animals and plants, is known as evolution.

APPLIED BRANCHES OF BIOLOGY

- [a] Applied Botany: Some important branches of applied botany are mentioned here.
 - (i) Agriculture-dealing with crops.
 - (ii) Horticulture-formation and maintenance of gardens.
 - (iii) Pharmacognosy-separation of active principles of medicines from organisms.
 - (iv) Forestry-conservation of forest.
 - [b] Applied Zoology: Some are given below.
 - (i) Sericulture-rearing of silkworms.
 - (ii) Apiculture-rearing of honey bees.
 - (iii) Lac culture-rearing of lac insect.
 - (iv) Poultry-rearing of fowl, duck etc.
 - (v) Pisciculture-rearing and cultivation of fish.
 - (vi) Animal husbandry-rearing and cultivation of cattle-like domesticated animals.

1.8. Matters to Recollect

- Fundamental concept of biology is concerned with life.
- Life is the well organised dynamic complexity of substances.
- Shape and size, protoplasmic composition, organisation of body, metabolism, growth, movement and locomotion, rhythmicity, reproduction, adaptation, mutability are some of the *characteristics of life*.
- Biology deals with the living organisms.
- Lamarck first coined the term biology in 1801.
- Ancient Indians specially Susruta and Charaka had some basic knowledge of biology. Although Aristotle discovered many things in biology yet biology as a scientific discipline did not develop before the early sixteenth century. The most important early biologists were Vesalius, Harvey, Robert Hook, Mendel, Darwin and many others who have founded the emergence of contemporary biology.
- Biological science *contributes* in the development of agriculture, medicine, horticulture, animal husbandry etc.
- Biology is the most demanding of all sciences because of its manifold importance. Scientists of modern *biotechnology* have been able to produce genitically improved variety of crops and they have successfully *cloned* animals and plants.
- Biological sciences have been developed in many directions, as a result many sub-branches in collaboration with physics, chemistry and with other branches of physical sciences have been developed, such as biophysics, biochemistry, bionics, exobiology etc.

Botany and Zoology combine to form biology. Again, biology has its pure branches of biology and applied branches of biology.

1.9. Summary

There is no real definition of life. But to the biologist, the word life is expressed in terms of characteristics of living organisms. Characteristics of life are the shape and size, protoplasmic organisation, metabolism, growth, movement, response to stimulus, reproduction, adaptation, evolution etc. In non-living object, those characters are absent. Biology may be defined as a branch of science which deals with the living organism.

Many ancient Indians specially Susruta and Charaka tried to classify plants and animals. Their classification was not fully scientific in modern point of view. They contributed many things in medicine. Aristotle was a genius and he contributed many things in biology yet the biology, was not regarded as a scientific discipline during his time. From the early sixteenth century many scientists of western world contributed much, as a result biology gradually established as a scientific discipline.

There is a profound scope of biology in relation to the production of food, clothes, disease remedy, public health, forest conservation, prevention of pollution, control of population explosion, control of flood and soil erosion, search of fuels, eugenics and even in space research.

Today biology is related to other branches of sciences and in collaboration with physics and chemistry two new branches are formed, such as biophysics and biochemistry. The biological science is divided into plants and animals. Due to manifold importance, biology comes in the forefront of all sciences. Biological science is very important in this millennium because of its branches like biotechnology, biomedical engineering, genetic engineering etc. Biology has its many sub-branches, both pure as well as in applied in nature.

1.10. Answers to Special Questions

[1] Who first proposed the term 'biology'?

Ans. The term biology was first proposed separately by two famous French naturalists Lamarck and Treviranus in 1801.

[2] What is the literal meaning of the term biology?

Ans. The literal meaning is the knowledge derived from living organisms. It is derived from two Greek words- $Bios \equiv life$, $logos \equiv knowledge$.

[3] What is the definition of 'biology'?

Ans. Biology may be defined as a branch of science that deals with the living organisms about their nature, life processes, relationship with the environment, evolution, inheritance etc.

[4] What is life?

Ans. Life may be defined as the external manifestation of the actions and interactions between the living organism and its environment.

[5] What is the basic material of life?

Ans. The basic material of life is the protoplasm.

[6] What is metabolism in living organism?

Ans. The sum total of biochemical changes in the protoplasm is known as metabolism.

[7] Why the anabolism is regarded as the constructive phase of metabolism? Ans. It is a process where new materials are added to the protoplasm and in this material potential form of energy is reserved for future use. Hence the anabolism is regarded as the constructive phase of metabolism.

8] Why the catabolism (katabolism) is regarded as the destructive phase of metabolism?

Ans. It is a process by means of which the stored potential energy in the protoplasm is converted into kinetic energy; as a result, materials of the protoplasm are destroyed and lost. Hence the catabolism is regarded as the destructive phase of metabolism.

[9] What is intussusception?

Ans. In living body, growth takes place by deposition of new materials in the protoplasm and this type of internal growth is known as intussuseption.

[10] What is acretion?

Ans. In non-living substance growth in volume takes place by simple deposition of identical matter on its outer surface and this type of growth is known as accretion.

[11] What is micropopagation?

Ans. It is a method of rapid vegetative multiplication of agricultural plants.

[12] What is 'biological control' of crop pests?

Ans. It is a method of protection of crops in the field by introducing living

organism which destroys the crop pest.

[13] What is the role of green alga Chlorella in the space travel?

Ans. Cosmonauts in the space travel keep the green alga Chlorella in the space craft. Chlorella uses the CO₂ which is being released by the cosmonauts during respiration inside the space craft for synthesis its own food. Thus the green alga removes the poisonous CO₂ and releases O₂ as a by-product during photosynthesis. This O₂ is utilized by the cosmonauts during breathing. In this way, the Chlorella helps in the space travel.

[14] What is eugenics?

Ans. Eugenics is a branch of science which deals with the improvement of human race genetically by selective control of reproduction.

[15] What do you understand by public health?

Ans. Public health is concerned with the activities that help to maintain the health of the human beings inhabiting in both rural and urban areas

[16] What is the role of Cassurma plant in soil erosion?

Ans. Cussurina is a sand binder tree. Hence plantation of this plant in sea side area prevents soil erosion from sea waves.

[17] What do you understand by cybernetics?

Ans. This branch of science has been formed in collaboration of biology with that of technology.

[18] What is bionics?

Ans. This branch of science has been developed in collaboration of biology with electronics.

[19] What is palaeontology?

Ans. The branch of science which deals with the principles of formation of fossils, its time scale and evaluation of fossils is known as palaeontology.

[20] What do you mean by biogeography.

Put / mark for correct statement :

digestion/assimilation/egestion.

Ans. This is a branch of science that deals with the global distribution of plants and animals.

EXERCISE

• A.	Long Answer type :				
[1]	Briefly discuss the characteristics of life.	(Ans. L1)			
[2]	Discuss the role of Susruta and Charaka in the development of ancient biology	(Ans. 1.3)			
[3]	Discuss the role of biology in the progress of agriculture and medicine	· (Ans. 1.5)			
[4]	Define life Describe briefly about the importance and application of biological				
(4)	the me the streng about the importance and appreciation of olological	(Ans. 1.1 and 1.5)			
151	Discuss the role of biological sciences in the progress of agriculture, medical science				
1-1	enaction and code of considering activities in the broditers of medical medical enterin	(Ans. 1.5)			
[6]	Discuss the role of biological sciences in the progress of agriculture, medical scien				
1-1	of natural oil.	. (Ans. 1.5)			
[7]	Discuss briefly the application and importance of biology in solving the follows				
	,, ,, ,, ,, ,, ,, ,, ,, ,,	(Ans. 1.5)			
	(a) In food production, (b) In control of population explosion, (c) In the maintenance				
	(d) In the control of environmental pollution, (e) In controlling flood and soil erosion, (f) In the field				
	space research.				
[8]	Write what you know about the importance of biology in this millennium	(Ans. 1.6)			
[9]	How is biology related to other sciences.	(Ans. 1.4)			
[10]	What do you understand by 'life' ' How biology is related to other sciences				
	55A A	(Ans. 1.1 and 1.4)			
• B.	Short Answer type: What is left ?	44 44			
[1]		(Ans. 1.1)			
[2]	Why nutrition is regarded as anabolic process?	(Ans. [.1)			
[3]	Why respiration is regarded as the destructive process of metabolism? What is mutability?	(Ans. 1.1)			
151	What is hipphysics?	(Ans. 1.1)			
161	Define bio-metrics	(Ans. 1.4.)			
[7]	Mention two branches of pure biology.	(Ans. 1.7)			
[8]	What do you mean by pharmacognosy?	(Ans. 1.7a)			
		(/400-1./4)			
• C.	Specific Answer type :				
111	What do you mean by assimilation ?	; (Ans. 1.1)			
[2]	What is secretion?	(Ans. 1.1)			
[3]	What is growth?	(Ans. 1.1)			
[4]	What is movement in living organism?	(Ans. 1.1)			
[5]	What is reproduction in plants and animals ?	(Ans. 1.1)			
[6]	What is senescence in living organism?	(Ans. 1.1)			
[7]	Who first coined the term 'biology'?	.E. 1999] (Ans. 1.2)			
• D.	Distinguish between:				
[1]	Anabolism and catabolism	(Ans. 1.1)			
[2]	Digestion and assimilation	(Ans. 1.1)			
[3]	Secretion and excretion	(Ans. 1.1)			
[4]	Intussusception and acretion	(Ans. 1.1)			
[5]	Movement and locomotion	(Ans. 1.1)			
[6]	Morphology and anatomy	(Ans. 1.7)			
[7]	Cytology and physiology	(Ans. 1.7)			
• E.	Short notes :				
[1]	Metabolism (Ans. 1.1) [2] Nutrition (Ans. 1.1) [3] Rhythmicity (Ans. 1.1) [4]	Bio-chemistry (Ans.			
	1.4				

[1] The process by means of which the undigested food matter is thrown out from the body is known as

- [2] Adjustment of the Every organism with the environment is brown as mutable to adaptat, as evolution.
- [3] Some and gradual changes of imparisor through successive generations is known as existing adoptation reproduction.
- [4] Jeans to dogs is first it that need by Corner Latter & Darwin
- [5] In collaboration of physics and bissings a new branch of science has descripted which is around so Historian Street and Complexical
- G. Fill in the blanks with correct word :
 - [1] All living organisms are composed of ---
 - [2] Surrium s an propose
 - [3] Respiration is a princise
 - [4] Protopleamic compusition is absent ist object
- [4] The branch of secree that leas will the diseases of living inganisms is known as
- H Put mark on Yes or No for correct answer :
- 111 I very living organizat has its own shape and size hes No.
- [2] Respiration is an anabolic process. You'led
- [3] In the issing organism and the classactivities are not puring on in a statemer featurer. Year his
- [4] Reproduction is one of the most important characteristic features of living body. Yes but
- [5] Organic evolution takes place in living organism. Yes No.

(F)		[6]	JH	tt -
1 egestion	[1]	protoplasm	111	Yes
adaptation	[2]	gr glasses,	[2]	400
l] evolution	[3]	catabolic	131	No
I Lamarck	141	non I ving	141	Yes
I his physics	151	pathology	[5]	10

Unit of Life

Topics Discussed: Tools and techniques Microscopes, Cell fractionation and tracer techniques; Cell as the basic unit of life; Discovery of cell; Cell theory; Unicellular and multicellular organisms; Pro, Meso and Eukaryotic cell types; Parts of eukaryotic cells and their description; A few comparisons

Cell is considered as the unit of life because each living organism is made up of one or more cells. The study or science of cells is known as cell biology or cytology (Gr. cyto = cell; logy = science or knowledge). Although these two terms are often used as synonyms, cytology specially refers to study of structure and composition of cells whereas cell biology includes study of both structure and function of cells and correlation between them.

2.1. Tools and Techniques: Microscope and Microscopy

As most of the cells are too small to be seen with naked (unaided) eyes, some tools and techniques are required to study their structures. The most important tool in the field of cytology is the **microscope** (*Gr.* mikros = small; skopein = to see).

A microscope is an instrument which gives a magnified image of the object and is used to examine minute objects that are not visible with naked (unaided) eyes. Microscopy means the use of microscopes for studying the cells.

In 1590, the two Jansen brothers of Holland, Francis Jansen and Zacharias Jansen, who were spectacle makers, first developed a compound microscope. Since then, various types of microscopes have been developed and the latest addition in this field is discovery of electron microscope by M. Knoll and E. Ruska in 1931 for which Ruska was awarded Noble prize in 1986. The detailed structure of cells revealed by electron microscopy is known as ultrastructure.

2.1.1. DIFFERENT TYPES OF MICROSCOPES

A microscope is comparable to human eye because both have lens systems, and in both, the images of the object are formed. The principle on which construction and utility of a microscope is based, is getting a magnified image of the object through lenses. Microscopes used in biological studies are mainly of two types—light microscope and electron microscope. Among these, the light microscope is used in the biology laboratory of a school or college whereas electron microscope is used for research purpose.

2.1.1.A. LIGHT MICROSCOPE:

In this type of microscope, light is used as a source of illumination. There are two common types of light microscopes—simple microscope and compound microscope. The simple microscope contains only one set of lens system known as eye piece, hence it has a low magnifying power. On the other hand, a compound microscope contains two sets of magnifying lens systems—objective (near the object) and eye piece (near the observer's eye). In a compound microscope, since two lens systems are used at a

time, the magnified real image formed by the objective lens is further magnified by the eye piece lens to form a virtual image which is seen by the viewer. Naturally, the magnifying power of a compound microscope is much higher (upto 1500 times). Construction (different parts) and use of simple and compound microscopes are described below.

Simple microscope:

Different parts of a simple microscope commonly used in biology laboratory are divisible into two types [A] mechanical parts (that form the frame work of the instrument and hold the optical parts) and [B] optical parts (that are concerned with formation of image by light rays).

- [A] Mechanical parts: They include [1] stand, [2] draw tube, [3] adjustment screw and [4] stage.
- [1] Stand-It is the main supporting part of the instrument consisting of a base (or foot) and a pillar. The base is a solid U or V shaped metal part with the help of which the instrument is placed on the table. The pillar is a metal-made, hollow, cylindrical part attached to the base vertically and it holds the mirror, adjustment screw, stage and draw tube.
- [2] Draw tube--It is a metal tube placed within the pillar. It holds the eye piece and can be moved up and down for proper focussing.

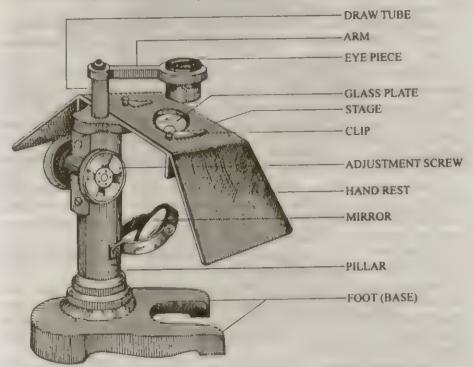


Fig. 2.1: A simple microscope.

[3] Adjustment screw—It is attached near the upper end of pillar on its back side. With the help of this, the draw tube and thus the eye piece can be moved up and down for proper focussing.

- [4] Stage—It is a glass- or metal-made rectangular platform, attached to the upper end of the pillar, on which the object (specimen) is placed. The metal stage contains a central hole fitted with glass (through which light rays reflected by the mirror fall on the object) and two clips (one on either side). On either side of the stage, an additional rectangular metal plate called hand rest may remain attached.
 - [B] Optical parts: They include [1] mirror and [2] eye piece.
- [1] Mirror-A revolving circular, concave mirror is attached at the lower end of the pillar. With the help of this, the light rays are reflected towards the hole of the stage and the object.
- [2] Eye piece—It is a short tubular part attached to the upper end of the draw tube. It is the sole magnifying lens system of a simple microscope and consists of one or two convex lens(es). It is so named because the viewer's eye is placed above it.

A simple microscope in often used in botany practical classes for dissecting a flower to observe its reproductive parts. It is also used to have a gross view of the tranverse section of stem and to examine lower plants like moss etc. It can magnify the object upto 20 times.

Compound microscope:

Like the simple microscope, a compound microscope also consists of— [A] mechanical parts and [B] optical parts as described below.

- [A] Mechanical parts: The mechanical parts of a compound microscope include—[1] stand, [2] body tube and draw tube, [3] nose piece, [4] stage and [5] adjustment screws.
- [1] Stand-It is the main supporting part of the instrument and consists of base, pillar, arm and inclination screw. The base is a V or U shaped, solid, metal-made part with the help of which the instrument is placed on the table. The pillar is the short vertical continuation of base on which the remaining parts rest. The arm is a curved part, the lower end of which is attached to the upper end of the pillar with the help of an inclination screw. The instrument is carried from one place to another by holding its arm and it can be inclined by pulling the arm.
- [2] Body tube and draw tube—The body tube is a wide cylindrical part attached vertically to the upper part of the arm. Another short and narrow tube called draw tube is attached to the upper end of the body tube. The upper end of draw tube holds the eye piece and the lower end of body tube holds the nose piece.
- [3] Nose piece—It is a revolving disc-like part attached to the lower end of the body tube. The objective lenses remain mounted on it.
- [4] Stage—It is a rectangular platform attached to the lower end of the arm and is positioned above the pillar. The microscopic slide to be examined is placed on it. The stage has a central hole for passage of light and pair of simple side clips or a mechanical stage clip for holding the slide. With the mechanical stage clip, the slide can be moved smoothly by using stage knobs.
- [5] Adjustment screws (or Focussing screws)—Two adjustment screws are present on the upper part of the arm, one of which is larger called **coarse adjustement screw** and the other is smaller called **fine adjustment screw**. These can move either the body tube or the stage to adjust the distance between the object and the objective lens through a rack and pinion system for focussing the object properly.

[B] Optical parts: The optical parts of a compound microscope include-[1] mirror, [2] sub-stage condenser, [3] objective and [4] eye piece.

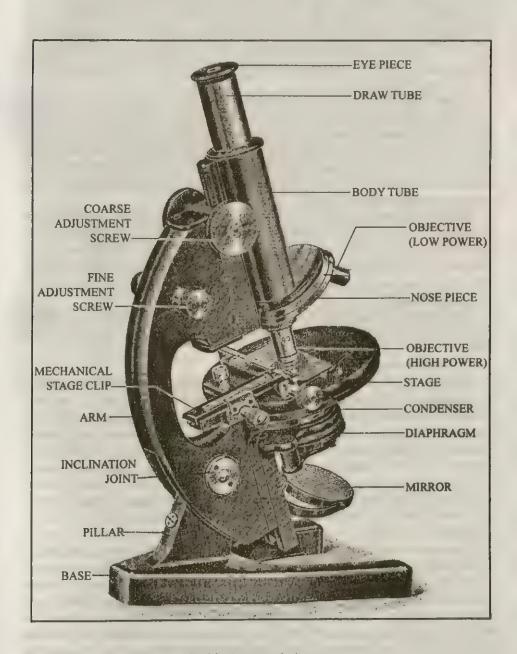


Fig. 2.2: A compound microscope.

[1] Mirror-A compound microscope contains a plano-concave mirror (i.e. one side plane and other side concave) attached to the pillar. The mirror can be rotated in any direction to reflect light to the condenser. The plane mirror is used when the object

is examined under low power objective and the concave mirror is used for examining the object under high power objective.

[2] Substage condenser—It is a lens system provided with a diaphragm (also called iris diaphragm). It is placed either within or beneath the stage. The condenser lens helps to converge a cone of light on the object present on the slide. The diaphragm is used to control the amount of light incident on the condenser lens. In a ordinary microscope, the position of substage condenser is fixed but in an advanced microscope, it can be moved vertically.

[3] Objective—A compound microscope contains 2 or 3 objective lenses of different magnifying powers, mounted on the nose piece, so that any of them may be placed in the line of light beam by rotating the nose piece. The ordinary compund microscopes commonly used in school or college laboratories contain 2 objectives—the shorter one is **low power** (10X) and the longer one is **high power** (40X or 45X). Advanced type of compound microscopes contain another objective lens called **oil immersion** lens having a higher magnifying power (100X).

[4] Eye piece—In an ordinary compound microscope, an eye piece is placed at the upper end of the draw tube, on which the viewer's eye is placed. It may be of different powers (usually 5X or 10X or 15X). It is a short, hollow cylinder having two lenses mounted on its either end. In an advanced type of compound microscope called binocular microscope, there are two eye pieces, so that the object can be viewed with both the eyes simultaneously.

A compound microscope is used to observe permanent slide preparations, stained fresh tissues and even unstained living tissues. It can magnify the object upto 1500 times.

2.1.1.B. ELECTRON MICROSCOPE:

The principle of electron microscope (EM) is analogous to that of compound microscope. The EM also uses a beam of radiation which is focussed on the specimen through condenser lens and the image is magnified by further lenses. But the difference is that, in EM (i) instead of light, a beam of electrons is used for image formation and (ii) instead of glass lenses, electromagnetic lenses are used to control the pathway of electron. The EM is like an upside-down compound microscope. The radiation enters at the top and the specimen is viewed at the bottom. The EM consists of a long, hollow, cylindrical column containing the following components from upper side downwards—an electron gun, a condenser lens, a specimen holder, magnifying lenses, and a fluorescent screen.

The electron gun present at the top of the column consists of a tungsten wire filament which releases a stream of electrons when heated by passing a high voltage through it. The inside of the column is kept under a high vacuum to prevent scattering of electrons by collision with air molecules. The electromagnetic condenser lens (situated in between the electron gun and the specimen) focusses the electron beam on the specimen. The specimen is placed on a specimen holder which is a small, thin, metal grid, perpendicular to the electron beam inside the column. The electromagnetic magnifying lenses are of two kinds—objective lens and projector lens. As electrons cannot be seen with the human eye, the image is made visible by shining the electrons onto a fluorescent screen. Thus, the enlarged image is produced on a viewing fluorescent screen, rather than being observed directly through the eye piece. The image can also be formed on a photographic

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film to have a permanent record of it. A photograph taken with an EM is called **electron micrograph**. Since the images produced by electrons do not have colour, the EM gives a black and white picture. The specimens for study in EM are treated with chemicals or dyes (*i.e.* stained) to enhance the contrast of the picture and live objects cannot be observed as such. Electron microscopes may be of two types **transmission electron microscope** (TEM) and **scanning electron microscope** (SEM).

In **TEM**, the electrons pass through the specimen to produce the image. With TEM, only very thin sections of a material or very small particles can be observed because electrons are easily absorbed by larger objects and cannot pass through them to produce the image. Those parts of the specimen which are more dense absorb the electrons and appear darker in the final picture. For a better contrast (*i.e.* density difference), the sections are stained (treated) with salts of heavy metals such as lead, uranium etc. This is necessary because most of the constituent elements in biological materials are of low mass and hence the constrast is poor.

In **SEM**, the image is produced due to reflection of electrons from the surface of the specimen. For this the specimens are coated with metals like gold, platinum etc. to create a reflecting surface. The electrons reflected from the specimen are used to form an image, which is displayed on a computer screen. The SEM gives a three dimensional view of a surface structure.

The electron microscope has a very high magnifying power (250,000 times or more) and resolution (TEM 0.5 nm and SEM 5-20 nm). It helps to examine the structure of cell components. However, the disadvantage of EM is that, living cells cannot be observed with this and the image is always black and white (in light microscope, coloured objects can be seen).

2.1.2. MAGNIFICATION AND RESOLVING POWER

These two terms are often used to denote the efficiency and usefulness of a microscope. However, they do not mean the same thing.

Magnification (or magnifying power) of a microscope means the ability of the instrument to enlarge the image of an object. It is given by the ratio of the size of retinal image with the instrument to the size of retinal image with unaided eye.

:. Magnification = Size of the retinal image with the instrument Size of the retinal image with unaided eye

The magnification of a compound microscope can be obtained by multiplying the magnifying power of the objective and eye piece lenses. The simple, compound and electron microscope can magnify an object upto 20, 1500 and 250,000 times respectively.

Resolution means ability to distinguish between two separate objects. In other words, resolution is the ability of an optical device to produce separate images of two closely placed objects. If two separate objects cannot be resolved, they will be seen as one object. The shortest distance between the two points that can be resolved (i.e. distinguished as two separate points) is called the **limit of resolution. Resolving power** of an optical system is the reciprocal of the limit of resolution, i.e. smaller the limit of resolution, higher the resolving power. The resolving power is expressed in terms of the limit of resolution. The resolving power of human eye is 0.1 mm (or 100 µm), compound microscope is 0.2 µm (or 200 nm) and electron microscope is 0.5 nm. That

means, we cannot see objects smaller than 100 µm, 200 nm and 0.5 nm with naked eyes, compound microscope and electron microscope respectively.

The resolving power (RP) of a microscope depends upon the wave length (WL) used and the numerical aperture (NA) of the objective lens. The RP of a microscope

will increase with decrease in the WL and increase in NA, i.e. RP $\propto \frac{1}{WL}$ and RP \propto

NA. The numerical aperture of a lens measures its light collecting ability. As the wave length of electrons are much shorter than visible light, the resolving power of electron microscope is far greater than light microscope.

Although, both magnification and resolving power of electron microscope are much higher than other microscopes, it should be clearly understood that the resolving power of an instrument is by no means dependent on its magnification. In an optical system, the image formed may not be magnified at all, but may be resolved into details. In another system, the image may be highly magnified but with no further details. For example, we enlarge photographs in order to see them more clearly, but if the enlargement is too high then the picture becomes blurred.

REVISION

Microscope—An instrument for viewing enlarged images of minute objects that are not visible with naked eyes.

Simple microscope—A light microscope using only one set of lens system (eye piece) for magnifying the object.

Compound microscope—A light microscope using two sets of lens system (eye piece and objective) for magnification.

Electron microscope—A microscope using electron beam and electromagnetic lenses for formation of enlarged images.

Magnifying power-Ability of a microscope to enlarge the image of an object.

Resolving power-The smallest distance between two points that can be distinguished by an optical system.

Microscope having highest magnifying power and resolving power-Electron microscope.

2.2. Cell Fractionation and Tracer Techniques

Microscopy helps us to understand the structure of cells and their components (organelles). However, other techniques are also needed for studying the functions of cell organelles. In order to study the function of a particular cell organelle, it is to be isolated from other components of the cell and it should be allowed to perform its normal functions in vitro (i.e. outside the body, in a test tube). For this, cell fractionation and tracer techniques are commonly used.

Cell fractionation: Cell fractionation means separation and isolation of individual components of a cell. It involves two techniques—homogenisation and differential centrifugation.

Homogenisation means breaking of cells by rupturing the cell membrane of a tissue specimen taken in a suitable medium (with correct pH, ionic composition and temperature). This is commonly done by grinding the cells in a glass homogeniser consisting of a tube and a close-fitting, beaded piston attached to a motor. The tissue is

taken in the tube with a suitable medium and the piston is rotated at a high speed. Homogenisation can also be done by applying osmotic shock or ultrasonic vibrations to the tissue specimen. The fluid obtained from homogenisation of a tissue is known as tissue (or cell) homogenate which contains all the components of the tissue suspended

The homogenate is then subjected to differential centrifugation for separating the cell components present in it. Centrifugation is a process in which the particles suspended in a fluid, tend to move outward when they are put to centrifugal force. It is done with the help of a motorised instrument called centrifuge having suspended test tubes that can be rotated horizontally at different speeds to exert centrifugal force. When different homogenates are taken in the test tubes and the centrifuge is rotated, the cell components tend to move outward and settle down depending upon their size and density. The faster the rotation of the centrifuge, the smaller will be the particles that will be sedimented. The centrifuge is rotated at a series of increasing speeds for increasing durations. After each speed, the supernatant (the liquid above the pellet) is decanted and recentrifuged at a higher speeded. Thus, a series of pellets containing cell organelles of smaller size are obtained. This is known as differential centrifugation. Very high speeds can be obtained in a special centrifuge known as ultracentrifuge which usually operates at a low temperature and in vacuum condition.

Tracer techniques: Tracer techniques involve use of isotopically labelled molecules and detection of the isotopes for the study of biological pathways and mechanisms. An isotope is a form of an element having the same atomic number (i.e. number of protons) and number of electrons as the common form of the element, but it differs in atomic weight (i.e. mass number) due to the difference in the number of neutrons. An isotope may be stable or radioactive depending on the relative number of protons and neutrons in its nucleus. An isotope is said to be stable if its nucleus does not undergo decay by emission of particles, whereas in case of radioactive isotopes, the nucleus undergoes spontaneous and constant decay by emitting particles to attain a more stable form.

Both stable and radioactive isotopes of an element are identical in chemical properties, and thus they undergo all the chemical and physical changes as the ordinary form of the element. Moreover, they can be detected at any time by atomic weight or radioactivity. Radioactive isotopes can be detected by their radioactivity through Geiger-Muller counter or other sensitive detectors even when present in very small quantity. Stable isotopes can be detected by their atomic weight through a mass spectograph. Thus, the course of an isotope through complex processes can be easily followed. Stable or radioactive isotopes used for studying the fate of a molecule in chemical, physical or biological processes are called tracers or tracer elements and the methods for such studies are called tracer techniques. Radioactive tracers commonly used in biological studies are C¹⁴, P³², H³ (tritium) etc. O¹⁸ is an important stable isotope used as tracer in biology.

Inorganic or organic compounds can be prepared with isotopes at specific positions in their molecules. Such a compound containing an isotopic element in its molecule is said to be 'tagged' or 'labelled' and is used as a tracer. When an isotopically labelled compound is administered to an animal (or a plant) or inculabated with tissue preparations, it undergoes the same fate as the unlabelled from of the compound and the isotopically labelled products can be decreted. Thus, the source, metabolic pathways and end products of biomolecules can be studied by using isotopically

tagged tracers. Tracers are also used for determining the (i) metabolic turnover of a substance, (ii) relative proportions of a substance being catabolized through different pathways. (iii) functional status of an organ, (iv) intestinal absorption of a nutrient, (v) mechanism and site of action of a hormone, (vi) blood level of a hormone (radio immuno assay), (vii) volume of body fluids, (viii) cardiac output, (ix) blood flow through an organ, (x) intracellular distribution of a substance (autoradiography) etc. Some common uses of C¹⁴, P³², H³ and O¹⁸ are given below.

C¹⁴ is the most common radioactive tracer used in metabolic studies. Some examples are–(a) After feeding C¹⁴ labelled glucose to rats, the liver glycogen contains C¹⁴ and C¹⁴O₂ is evolved showing that (i) glucose is converted to glycogen in liver and (ii) the C atom of glucose is excreted as CO₂. (b) When C¹⁴ labelled acetyl CoA is administered, the C¹⁴ is found to be present in citric acid, fatty acids, cholesterol etc. showing formation of these products from acetyl CoA. (c) On feeding C¹⁴ glucose, all the intermediate compounds formed in glycolysis, TCA cycle, glycogenesis etc. become isotopically tagged showing metabolism of glucose through these pathways. (d) The sources of carbon atoms of porphyrin have been determined by using C¹⁴ tagged acetate and glycine. (e) If photosynthesis is conducted in an atmosphere containing C¹⁴O₂, the sugar produced contains the C¹⁴ showing that CO₂ is the source of C atoms of the sugar.

P³² (a radioactive tracer) is mainly used to study the phosphorylation reactions. For example, if P³² labelled inorganic phosphate (H₃P³²O₄) is used in *in-vitro* experiments with tissue slices or tissue extracts, it becomes incorporated in phosphorylated intermediate compounds of glycolysis. By labelling the bacteriophage DNA with P³², it has been shown that the DNA is the genetic material of bacteriophage. By using P³² labelled di-isopropyl fluorophosphate (DFP), an inhibitor of certain enzymes like trypsin and chymotrypsin, it has been shown that the amino acid serine is the active site of these enzymes.

H³ (tritium) is a radioactive isotope. It is used as a tracer in the form of tritium oxide (THO) for determination of total body fluid volume. THO distributes throughout all body fluids. So, the total volume can be obtained by determining the THO space.

 O^{18} is a stable isotope (non radioactive tracer) that has been used to trace the source of O_2 liberated in photosynthesis (Hill reaction or light reaction). When O^{18} labelled water (H_2O^{18}) is used in photosynthesis, O_2^{18} is liberated. This proves that water is the source of oxygen liberated in photosynthesis.

REVISION

Cell fractionation-Separation of cell components.

Homogenisation-Rupturing of cells by applying mechanical or osmotic or ultrasonic shock.

Homogenate—The fluid obtained from homogenisation of cells, containing all the cell components.

Centrifugation—Sedimentation of particles suspended in a fluid due to centrifugal force.

Centrifuge-The instrument for centrifugation.

Tracers (or tracer elements)—Isotopic elements used to study the fate of a molecule.

Tracer techniques-Methods for studying the fate of a molecule by labelling it with a tracer.

2.3. Cell as the Basic Unit of Life

All living organisms are composed of cells that originate from pre-existing cells. An organism may be made up of only one cell or more than one cells. Those organisms which are made up a single cell, are called unicellular organisms e.g. bacteria, Chlamydomonas, Yeast, Amoeba etc. On the other hand, those organisms which are made up of more than one cells, are called multicellular organisms. Multicellular organisms may be made up of only a few cells (e.g. some algae or fungi) to several billion cells (e.g. big trees, human beings and large animals like tiger, elephant, whale etc.). The life of every organism, whether plant or animal, begins as a single cell. The unicellular organisms complete their entire life cycle as a single cell, while multicellular organisms begin their life from a single cell, which in course of life divides repeatedly to increase the number of cells for forming the many celled body. Thus, the cells are considered as the building blocks or structural units of a living body. Each cell has its own function. In the body of a multicellular organism, a number of functionally different types of cells exist together. Actually, the activities of such an organism are sum total of the co-ordinated activities of its constituent cells. Thus, the cells are not only the building blocks of the body but they are also the functional units of life.

In a multicellular organism, certain cells become specialized to perform specific functions. The cells having a common origin and similar but specific function constitute a **tissue** (e.g. muscular tissue or nervous tissue of animals, vascular tissue of plants etc.). Different types of tissues collectively form an **organ** which performs some specific functions (e.g. kidney, heart, liver etc. of animals and leaf, flower etc. of plants). Several organs performing some specific functions together constitute an **organ-system** (e.g. digestive system, circulatory system, excretory system etc.). The different organ-systems of an organism exhibit an unique example of **division of labour**.

A cell is made up of a jelly-like material called **protoplasm** surrounded by a covering. The protoplasm consists of various components (organelles and inclusions) and is considered as the **physical basis of life**. Each cell exhibits all the characteristics of life e.g., respiration, metabolism, growth, reproduction etc. through its components. Thus, all the activities of an organism are present in miniature form in each cell. This is why, a cell is considered as the basic unit (i.e. structural and functional unit) of an organism.

2.3.1. DEFINITION OF CELL

Because of the great diversity in the structure of different cells, it is difficult to give a precise but complete definition of cell. For this reason, the cell has been defined in a number of ways by different cytologists. From these, a few important ones are given below.

1. Cell is a very small mass of protoplasm, which is independently capable of

expression of all the characteristics of life.-Schultz (1825-1874)

2. Cell is an unit of biological activity, delimited by a semipermeable membrane and capable of self reproduction in a medium free from other living systems. -Loewy and Siekevitz (1969)

3. The cell is a physical entity and the basic unit of life Swanson and Webster

(1978).

4. The cell is the structural and functional unit of life.—De Robertis (1979).

Although all the above definitions are more or less correct, each of these is incomplete

in one or other respect. By combining the relevent facts from these, an acceptablee definition of cell may be given as follows-

Cell is the structural and functional unit of life, which is made up of a small mass of protoplasm delimited by a semi permeable membrane and is capable of self reproduction without any living medium.

According to this definition, bacteria can of course be called as cells but a virus cannot be considered as a cell, because viruses do not possess a semi permeable membrane and they cannot reproduce without another living medium (host cell). In fact, viruses are placed in between living and nonliving matters because although they lack the so called protoplasm (the chief characteristic of life), they can reproduce (a characteristic feature of living organisms). Thus, viruses are grouped as accilular living organisms.

2.3.2. SHAPE OF CELL

There is a large variation in the shape of different cells; but generally, the cells of a particular type present in a particular organ of the individuals belonging to the same species are more or less similar in shape. The cells may have different shapes such as

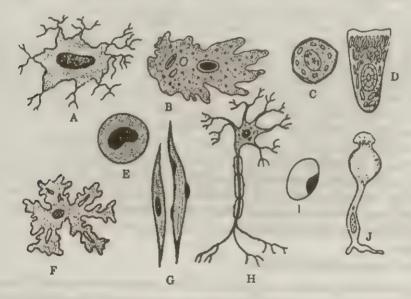


Fig. 2.3: Animal cells of different shape.

A-Bone cell, B-Amoeba, C-Hepatic cell, D-Epithelial cell, E-Blood cell, F-Pigment cell,

G-Muscle cell, H-Nerve cell, I-Adipose tissue cell, J Goblet cell.

spherical, oval, cubical, columnar, rod like, flat, spindle shaped or fusiform, conical, flask shaped, irregular or polygonal, branched, ciliated, flagellated, tailed (with a tail like structure) etc. The shape of a cell is fundamentally correlated with its function. In other words, it can be said that a cell acquires the shape which is most suitable for its function. For example, the cells of pulmonary alveoli and renal glomeruli that are responsible for exchange of materials are flattened, the secretory cells are cubical or columnar so that they can accumulate the secretory materials, contractile muscle cells are cylindrical (elongated fibre like), motile sperm cells have tail, and so on. It can be

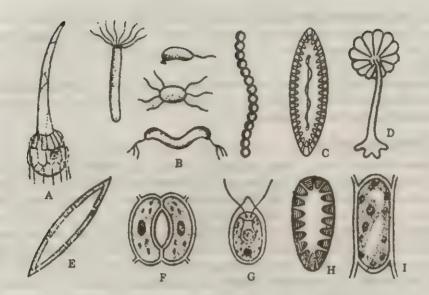


Fig. 2.4: Plant cells of various shape.

A-Stinging hair, B-Bacterial cell, C. Diatom, D-Acetabulana, E. Sclerenchyma cell, F. Guard cell, G-Alga cell, H. Stone cell, I. Epidermal cell of leaf

mentioned here that certain cells such as amoeba, blood cells, etc. are capable of frequently changing their shape.

2.3.3. SIZE OF CELL

Like the shape, the size of cells is also extremely variable. Majority of cells are very small and microscopic. Hence, for measurement of cells and their different parts, smaller units of length such as micron (μ) , millimicron $(m\mu)$ and angstrom (A) are used. Now a days the terms micron and millimicron have been replaced by micrometre (μm) and nanometre (nm) respectively. The relation between these units is as follows.

1 mm =
$$\frac{1}{1000}$$
 m = 0.001 m = 10⁻³ m = 10³ μ m = 10⁶ nm = 10⁷Å
1 μ or 1 μ m = $\frac{1}{1000}$ mm = 0.001 mm = 10⁻³ mm = 10⁻⁶ m = 10³ nm = 10⁴Å
1 m μ or 1 nm = $\frac{1}{1000}$ μ m = 0.001 μ m = 10⁻³ μ m = 10⁻⁶ mm = 10⁻⁹ m = 10Å
1Å = $\frac{1}{10}$ m μ (nm) = 0.1 nm = 10⁻¹ nm = 10⁻⁷ mm = 10⁻¹⁰ m

The smallest cells known so far are bacteria (unicellular micro-organisms) called Mycoplasma or PPLO (Pleuro pneumonia like organisms) which are $0.1-0.5~\mu m$ in size. However, a few cells are quite big and visible with naked eyes. Mammalian neurons, especially those extending from spinal cord to the lower end of the feet are the longest cells. These may be 1 metre or more in length. Eggs of ostrich are the biggest (largest in volume) cells. The cells of Acetabularia, a mushroom shaped marine

alga, are the largest unicellular plant cells (5-10 cm in length). Among the multicellular plants, the phloem fibre cells of Ramie plant (*Boehmeria nivea*) are the longest plant cells and may be about 55 cm. in length. Cotton and jute fibre cells are also long enough.

The size of a cell is governed by three factors:—(i) the nucleo-cytoplasmic ratio or the ratio of nuclear volume to cytoplasmic volume, (ii) the ratio of cell surface to cell volume and (iii) the rate of metabolism.

2.4. Discovery of Cell

Robert Hooke (1665), a British engineer, is credited with the discovery of cell. He examined thin sections of cork under a simple microscope devised by him and observed numerous closely packed, air filled chambers having a honey comb like appearance. He termed these chambers as "cell" (from the Latin word cella = hollow space) and illustrated it with sketches in the book Micrographia written by him. As we know, cork is a non-living (dead) matter. Thus, in reality the cells described hy Hooke were merely chambers devoid of protoplasm and surrounded by the dead cell wall. The Dutch businessman cum scientist Anton Van Leeuwenhoek (1632-1723) devised a

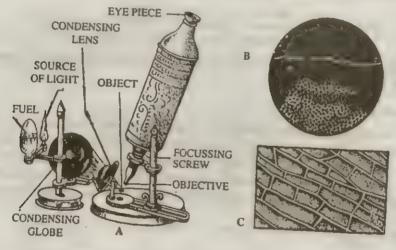


Fig. 2.5 : A The microscope of Robert Hooke ; B & C-The structure of cork as observed by him (C-enlarged view).

much improved type of microscope with the help of which he first examined various living cells such as bacteria, protozoa, sperms, muscles, nerves, red blood cells of fish etc., in 1674 and he noted the presence of a fluid matter within these cells. One hundred fifty years later, in 1824, the French cytologist **Dutrochet** suggested that all animals and plants are made up of cells. In 1781, **Fontana** observed a more or less spherical structure at the centre of the cells. After 50 years, in 1831, **Robert Brown** of Scotland noticed the presence of a similar spherical structure at the centre of cells in orchid leaves and termed it as **nucleus**. He postulated that the nucleus is the most vital part of the cell. **Wagner** in 1832, observed the existence of **nucleolus** within the nucleus. In 1835, **Felix Dujardin** of France noted the presence of a semiliquid, jelly like material within cells and termed it as **sarcode**. **Purkinje** in 1839, replaced the name sarcode by the term '**protoplasm**', which was later widely circulated and popularised hy **Hugo**

Von Mohl in 1846. Max Schultz (1836) described protoplasm as the 'physical basis of life' and this idea was strongly supported by Thomas Henry Huxley in 1868.

2.5. Cell Theory

Two German scientists, M. J. Schleiden (a botanist) in 1838 and Theodor Schwann (a zoologist) in 1839, independently expressed their ideas about plant and animal cells respectively. Because of the resemblance in their views, the so called **cell theory** was proposed in 1939 by combining the ideas of Schleiden and Schwann, which states that—

[1] All living organisms are made up of one or more cell(s), i.e. cell is the structural unit of all living beings.

[2] Each cell can function individually, i.e. a cell is the functional unit of a living body, but the cells work in an integrated manner within the whole body.

[3] Each organism originates from a single cell.

Later Rudolf Virchow in 1855, further added that all cells originate from division of pre-existing cells and that the flow of life is maintained from generation to generation through the cells.

2.5.1. EXCEPTION TO CELL THEORY: ACELLULAR ORGANISMS

After the discovery of viruses, the cell theory was criticised and it became apparent that there are some living organisms to which the cell theory is not applicable. Such living organisms are called **protobiota** (*Gr. protos* = first, *bios* = life). They include viruses, viroids, and prions, which do not have the protoplasm proper. The **viruses** are made up of an outer protein coat called *capsid* covering an inner nucleic acid (genetic material) which is either DNA or RNA. The **viroids** are virus like organisms having no capsid and its nucleic acid is RNA. The **prions** are simplest organisms in which the body is made up of a basic protein only, formed by 250 amino acids.

In addition to the protobiota, certain algae (e.g. Vaucheria) and fungi (e.g. Rhizopus, Mucor etc.) are also thought to be exceptions to the cell theory because they are coenocytic in nature (i.e. they are made up of an undifferentiated, multinucleated mass of protoplasm).

2.6. Unicellular and Multicellular Organisms

Lower group of living organisms such as bacteria, plants like some algae (Chlamydomonas) or some fungi (Yeast) and animals like protozoa (Amoeba, Paramoecium) are unicellular (i.e. they are made up of a single cell). Most of the other plants and animals are multicellular (made up of many cells). The number of cells in an organism is proportional to its size. Generally sedentary animals (e.g., sponge etc.) possess greater number of cells in respect to more active and motile animals (e.g., birds, insects etc.) of same size. The number of cells in a healthy adult man may range between 6-10 billions, whereas that in a big tree may be in the order of several billions (1 billion \equiv 1 million millions; Gr. Brit.).

The single cell of an unicellular organism performs several functions like absorption of nutrients, exchange of gases with the environment, metabolism, excretion etc. for its survival. For this, the cell has to be large enough to accommodate different organelles in it and it must have sufficient surface area to carry out the exchange functions. As a cell increases in volume, its surface area also increases but not proportionately. Surface area to volume ratio of a cell is important for its survival because the volume determines the rate of metabolic activity of the cell and the surface area determines the rate of

absorption of required materials and release of waste products by the cell. As a living organismm grows, its need for intake of materials from outside and rate of waste production increases at a faster rate than that of surface area. For this reason, cells are usually tiny and large organisms have many cells of small size (instead of only one cell or a few cells of large size). This helps to maintain the surface area to volume ratio. Moreover, the covering membrane of some cells become folded to form microvilli, which increases the effective surface area for better absorption and waste disposal. In multicellular organisms, there is a division of labour, and the cells get differentiated and specialized to perform different functions such as secretion, absorption, photosynthesis, transport of materials, reproduction etc. Even some dead cells play some important roles. For example, in animals, the dead cells of skin protect the inner living cells. In plants, the dead cells of xylem vessels and tracheids perform conduction of water. Thus, a multicellular organism having various types of cells with division of labour is more efficient than an unicellular organism and has better survival abilities which is enhanced by the following two facts-(i) Even though the cells are differentiated achieving a high degree of specialization, there is an unique co-ordination between their functions. (ii) Even if some cells die, the living cells multiply and replace the lost cells to ensure uninterrupted life activity.

The cells of multicellular organisms can be grouped under three categories on the basis of the level of their differentiation:

(i) Undifferentiated cells—These are mother cells capable of mitotic division for proliferation and growth of a tissue, e.g., stem cells of animals and meristematic cells of plants.

(ii) Differentiated cells—These are post mitotic cell which become specialized to perform specific functions and show division of labour, e.g., red blood cells for oxygen transport, muscle cells for movement, mesophyll cells for photosynthesis etc.

(iii) Dedifferentiated cells—These are differentiated cells which revert back to undifferentiated state by losing their specialization, when required. These are important for secondary growth, regeneration and wound healing.

All cells of a multicellular organism are derived from a single cell and carry the same genetic material, but they undergo specialization and show diversity of functions. Moreover, cells of all organisms, whether multicellular or unicellular, have some similarities in structure, molecular organization and activities. Thus, the cells show unity among diversity of life.

2.7. Prokaryotic, Mesokaryotic and Eukaryotic cell types and their Comparative Study

In 1957, Dougherty classified cells on the basis of structural organisation of their nucleus, into two main types-prokaryotic cells and eukaryotic cells. Prokaryotic cells are those that possess a primitive type of nucleus, devoid of nuclear membrane and chromosomes, i.e. they do not have a true and organised nucleus (Gr. Pro = primitive; karyon = nucleus). Eukaryotic cells, on the other hand, are those that possess a true or well organised nucleus having typical chromosomes and nuclear membrane (Gr. Eu = good or true or normal; Karyon = nucleus). Later, Dodge (1966) and others proposed that there is a third cell-type that can be placed in between prokaryotic and eukaryotic cells, which they called mesokaryotic cells (Meso = intermediate type; Karyon = nucleus).

Prokaryotic cells are primitive plant cells having the simplest organisation. They

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include the cells of bacteria, blue-green algae, mycoplasma (or PPLO, pleuro pneumonia like organism), rickettsiae and spirochaete. Prokaryotic cells are generally smaller than eukaryotic cells. A prokaryotic cell is made up of a mass of protoplasm surrounded by a cell covering. Every prokaryotic cell is invariably bounded by a complex cell wall. Beneath the cell wall lies the plasma membrane which surrounds the protoplasm. The plasma membrane may be invaginated to form internal membranous structures. Unlike the eukaryotic cells, the protoplasm of prokaryotic cells are not separated into nucleus and cytoplasm. The genetic material is localised within a discrete region called nucleoid or genophore or chromatin body, which is made up of DNA thread(s). The DNA is neither complexed with histone proteins nor does it form chromosomes. The nucleoid is not separated from the surrounding cytoplasm by any delimiting membrane. Thus, the genetic material (nucleoid) of prokaryotic cells is not considered as a true nucleus. The prokaryotic cells do not have membrane bound organelles like mitochondria, plastids, endoplasmic reticulum, Golgi body etc. However certain infoldings of the plasma membrane called mesosomes (or desmosomes) may contain respiratory enzymes, and thus, function as substitute of mitochondria. Photosynthetic or other pigments may be present in membranous vesicles (chromatophores) or discs (thylakoids) or tubules (lamellae), that are considered as substitute of plastids. Prokaryotic cells contain ribosomes and inclusion bodies that remain freely scattered in the cytoplasm.

Eukaryotic cells are in general larger and more organised than prokaryotic cells. Most plant and animal cells fall under this category. These cells are also made up of a mass of protoplasm surrounded by a covering. In all eukaryotic cells, the protoplasm is bounded by a plasma membrane. The plant cells possess an additional, rigid outer covering, the cell wall, which is absent in animal cells. Therefore, the plant cells have a fixed shape while the animal cells have a variable shape. The protoplasm of all eukaryotic cells is clearly divisible into cytoplasm and nucleus. The nucleus is well organised, which contains nuclear material enclosed by a double layered membrane (nuclear membrane). Such a membrane bound nucleus is considered as the 'true nucleus' because it is easily distinguishable from the cytoplasm. The genetic material (DNA) present in the nucleus remains combined with histone proteins and forms the chromosomes. The cytoplasm of eukaryotic cells has a highly complex organisation and contains several membrane bound organelles (e.g. mitochondria, plastids, endoplasmic reticulum, Golgi body etc.) having specific functions. Plastids are present in plant cells but absent in animal cells. Ribosomes are mostly attached to endoplasmic reticulum and some of them may remain freely scattered in the cytoplasm. The cytoplasm also contains various inclusion bodies, in which different materials remain stored.

The term 'mesokaryotic cell' was introduced to represent those cells that are intermediate between prokaryotic and eukaryotic types, e.g., the cells of certain algae like Gymnodinium, Perulinium etc and protozoa like Noctiluca. The mesokaryotic cells possess a membrane bound organised nucleus with chromosomes but the chromosomes contain acidic non-histone protien (instead of the basic histone protein of the eukaryotic chromosomes). In these cells, the mitotic spindle is not formed and mitosis does not occur. However, the term 'mesokaryotic cell' is no longer used in modern cell biology and such cells are considered as eukaryotic cells that have retained some features of prokaryotic cells.

2.7.1. COMPARISON BETWEEN PROKARYOTIC, MESOKARYOTIC AND EUKARYOTIC CELLS.

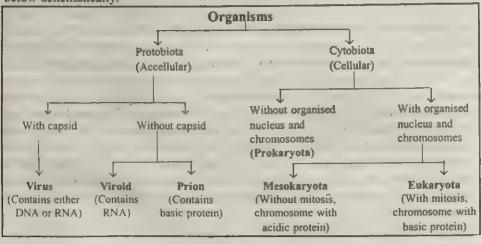
Character	Prokaryotic cell	Mesokaryotic cell	Eukaryotic cell
1. Nucleus and chromosome	Absent	Present	Present
2. Chromosomal protein	Absent	Acidic (Non-histone)	Basic (Histone)
3. Centromere	Absent	Absent	Present
4. Mitotic apparatus	Absent	Absent	Present
5. Cell division	By duplication of DNA	By amitosis	By amitosis, mitosis and meiosis
6. Celi wall	Present	Absent	Present in plant cells
7. Ribosome	70 S type	80 S type	80 S type
8. Centrosome	Absent	Absent	Present in animal cells
9. Flagella	Simple	Complex	Complex

2.7.2. CLASSIFICATION OF ORGANISMS ON THE BASIS OF CELL ORGANISATION

On the basis of cellular organisation, living organisms are classified broadly into two groups-protobiota (or acellular organisms) and cytobiota (or cellular organisms). The protobiota includes-(i) Viruses, (ii) Viroids and (iii) Prions as described earlier (Art. 2.5.1). The cytobiota are of three groups depending on their nuclear organisation:-

- (1) Prokaryota or organisms made up of prokaryotic cells, e.g. bacteria, blue-green algae etc.
- (ii) Mesokaryota or organisms made up of mesokaryotic cells e.g. certain algae like Gymnodinium, Peridinium etc. and protozoa like Noctiluca.
- (iii) Eukaryota or organisms made up of eukaryotic cells, e.g. higher plants and animals.

The classification of organisams on the basis of their cellular organisation is shown below schematically.



REVISION

Unicellular organism-A living organism made up of a single cell.

Multicellular organism-A living organism made up of many cells.

Prokaryotic cell-A cell without a true (membrane bound) nucleus.

Nucleiod-The nuclear (genetic) material of prokaryotic cells, not surrounded by a nuclear membrane.

Eukaryotic cell-A cell with a true (membrane found) nucleus.

Mesokaryotic cell—A cell having membrane bound nucleus and chromosomes with non-histone protein, but lacking mitotic apparatus.

Protobiota-Acellular organism or organism with non-cellular organisation.

Viroid-A protobiota consisting of a single RNA molecule without a protein coat.

Prion-A protobiota made up of a basic protein only.

Cytobiota-Cellular organism or organism with cellular organisation.

Prokaryota-A cytobiota made up of prokaryotic cell.

Eukaryota-A cytobiota made up of eukaryotic cell.

Mesokaryota-A cytobiota made up of mesokaryotic cell.

2.8. Parts of Eukaryotic Cell

All eukaryotic cells are delimited by a cell covering, within which the protoplasm remains enclosed. In all plant and animal cells, this covering is a living membrane called cell membrane or plasma membrane. Plant cells possess an additional outer covering called cell wall which is made up of nonliving matters. The protoplasm of

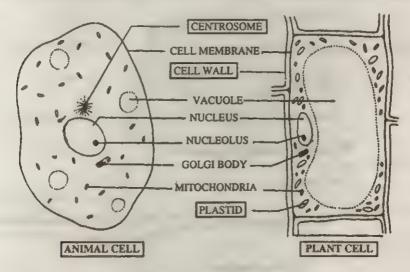
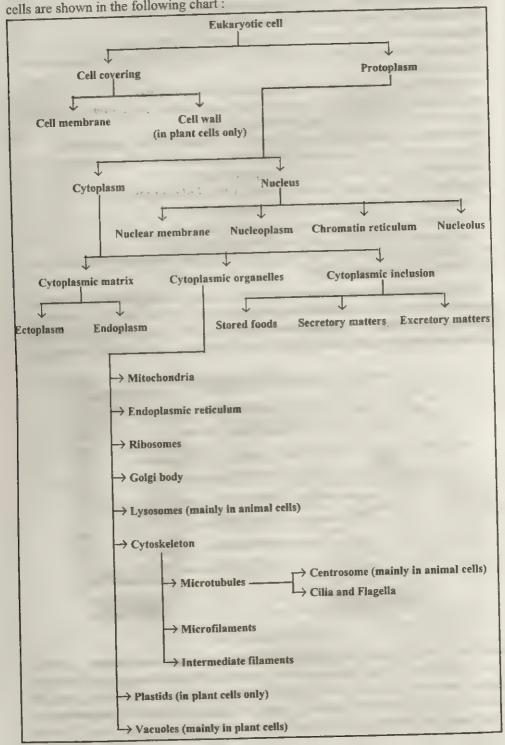


Fig. 2.6: Eukaryotic cell.

eukaryotic cells is clearly divisible into two parts—cytoplasm and nucleus. The fluid part of cytoplasm is called matrix which is composed of various organic and inorganic matters dissolved in water. Some living (membrane bound) and nonliving particles remain scattered within the matrix; these are called cytoplasmic organelles and cytoplasmic inclusions (or ergastic substances or deutoplasm) respectively. The well

organised nucleus contains four distinct parts-nuclear membrane, nuclear reticulum (or chromatin reticulum), nucleolus and nucleoplasm. The different parts of eukaryotic cells are shown in the following chart:



It should be noted that majority of the components mentioned in the preceeding chart are present in all eukaryotic (both plant and animal) cells, whereas the remaining

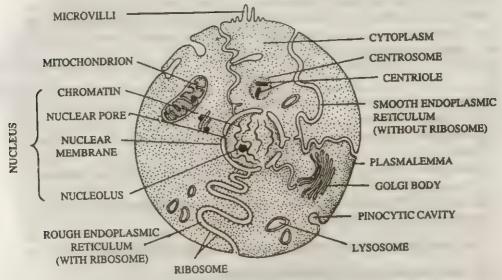


Fig. 2.7: A typical animal cell.

ones occur either in plant cells or in animal cells. For example, cell wall and plastids are found in plant cells only, whereas centrosome and lysosome are seen mainly in

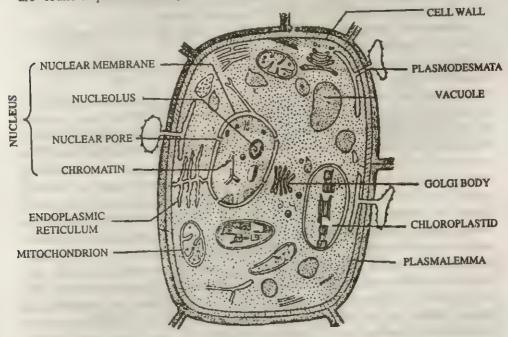


Fig. 2.8: A typica! plant cell.

animal cells. It is interesting to mention that even those components that are found in all cells are not equally well developed and organised in different types of cells.

Generally, a particular component having a specialised function is found to be more developed in cells concerned with that type of function. For example, the cells concerned with active (energy dependent) processes *e.g.* secretion, absorption, *etc.*, possess greater number of well organised mitrochondria; the cells engaged in protein synthesis contain more ribosomes; motile cells possess flagella or cilia, and so on. Thus, we see that the structure of a cell is nicely correlated with its function.

REVISION

Cytoplasm-The extranuclear protoplasm.

Nucleoplasm-The protoplasm of the nucleus.

Hyaloplasm or cytosol-The cytoplasmic matrix or the soluble fraction of the cytoplasm.

Deutoplasm—The cytoplasmic inclusions or the collection of non living substances of cytoplasm formed by the cell.

Ectoplasm (or Plasmagel)—The narrow peripheral non granular part of cytoplasm. Endoplasm—The central granular part of cytoplasm.

DESCRIPTION OF DIFFERENT PARTS OF EUKARYOTIC CELL

2.9. Cell Membrane or Plasma Membrane

Definition: The thin, elastic and semi-permeable living membrane that surrounds the protoplasm of a cell is called cell membrane or plasma membrane or plasmalemma.

In 1856, Nageli and Cramer reported about the existence of cell membrane. Later, the famous botanist Plowe (1931) named it as plasmalemma.

Occurrence: Plasmalemma is found in all living eukaryotic (both plant and animal) as well as prokaryotic cells.

Origin: Plasma membrane is believed to be formed by modification of the peripheral layer of cytoplasm.

Structure: In animal tissues, the plasma membrane alone forms the boundary of a cell, whereas in plant cells, there is an additional covering of cell wall that surrounds the plasma membrane externally. The plasmalemma is a very thin membrane that covers the protoplasm. Under light microscope, it is not clearly visible and appears simply as a thin dense line at the boundary of protoplasm, forming a marginal zone between the cytoplasm and the extracellular fluid. The cell membrane may be smooth (e.g. Amoeba) or thick (e.g. ova of certain marine invertebrates). Generally, it is evenly distributed around the cytoplasm, but in some cases it may be modified and thrown into folds to form inward or outward projections. In animal cells such as those found in intestinal mucosa or renal tubules, the cell membrane is externally folded to form minute fingerlike projections called microvilli at the apical (luminal) border of the cells. This increases the surface area of the cells for a better exchange of materials. In certain cells (e.g. epithelium of proximal tubule of kidney), the microvilli are very prominent and large in number so that the cells appear to be brush-bordered. Sometimes the cell membrane may possess sac-like temporary vacuoles at its inner side (due to infolding of the membrane). These vacuoles may be filled with either a solid or liquid material and are called phagocytic or pinocytic vacuoles respectively. The phagocytic vacuoles are also called phagosomes, while the pinocytic vacuoles are called pinocytic vesicles or pinosomes. Some cells may again exhibit processes called cilia (numerous and minute hair-like) or flagella (fewer in number but much larger) on the cell membrane, that are cytoplasmic projections covered by the plasma membrane; example—Paramoecium, cells of mucous membrane of trachea, etc. The plasmalemma may invaginate to form a branched tubular structure, called lamella (pl. lamellae), which forms tubular organelles. In the cells of Amoeba, the plasmalemma forms temporary outgrowth-like structures called pseudopodia (sing. pseudopodium) that help in locomotion of the organism.

In animal tissue, the adjacent cells are not usually in close contact throughout their borders; there is a space of about 10-20 nm between them, filled with interstitial fluid. Nevertheless, there are several types of linkages (e.g. desmosomes, tight junctions, terminal bars, gap junctions etc.) at places between the adjacent cell membranes, that help to maintain the structural and functional integrity of the tissues.

Ultrastructure or molecular (or chemical) structure of cell membrane :

The modern concept about the ultrastructure of cell membrane is based on the facts gathered from studies involving electron microscopy, chemical analyses and functional

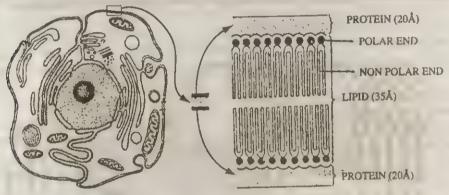


Fig. 2.9: The trilamellar structure of plasmalemma.

characteristics (i.e. property of permeability). According to **Danielli** and **Davson** (1935), the plasmalemma is a **trilamellar structure** made up of lipid and protein (hipoprotein).

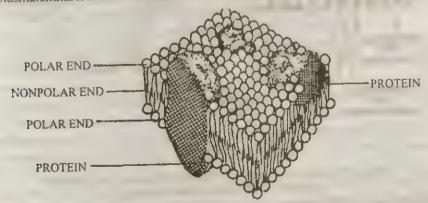


Fig. 2.10: Three dimensional structure of cell membrane. Fluid mosaic model of Singer and Nicolson.

The outer and inner dense layers are made up of protein whereas the lighter middle layer is made up of lipid. Thus, the two protein layers, one on either side of a cell

membrane sandwiches the middle lipid layer. Robertson (1956) suggested that all other membranous components of a cell (i.e. the membranous covering of various cytoplasmic organelles) also have a trilamellar structure made up of protein-lipid-protein (P-L-P). Thus, he considered the trilamellar (P-L-P) structure as the unit of all living membranes and termed it (P-L-P membrane) as unit membrane.

The average thickness of cell membrane is 75Å (7.5 nm), each of the two protein layers being about 20Å and the middle lipid layer being about 35Å thick. The lipid layer is made up of phospholipid molecules arranged in double layers (i.e. bimolecular phospholipid layer). One end of the phospholipid molecules (which consists of phosphorus-carbon-nitrogen part) is hydrophilic and is called the **polar end** as it is electrically charged. The remainder of the phospholipid molecule, made up of long chain fatty acids, is hydrophobic and electrically neutral; it is called the **non-polar end**. The polar ends of the bimolecular phospholipid layers are oriented in opposite directions, so that they remain attached to the adjacent protein layer on either side. The non-polar ends of the two phospholipid layers remain attached to each other at the inner side of the membrane and are arranged perpendicularly to the membrane.

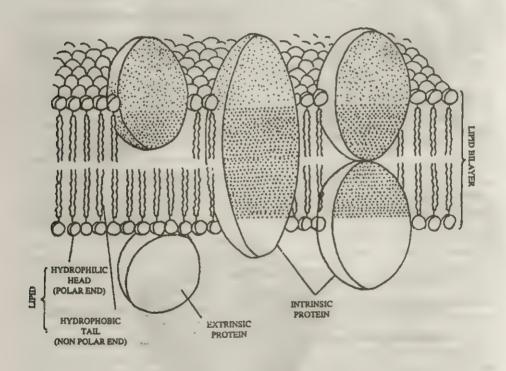


Fig. 2.11: Fluid mosaic model of cell membrane showing the lipid bilayer and the position of intrinsic and extrinsic proteins in it.

Some amount of cholesterol and carbohydrate are also present in the cell membrane. The cholesterol probably remains closely packed with the phospholipid, thereby increasing the stability of the membrane. The carbohydrate is present as a thin

polysaccharide coat, known as glycocalyx, on the outer protein layer of the cell membrane, thus forming a mucoprotein. Plasmalemma of different cells also contain various enzymes and metal ions such as Na*, K*, Mg**, Ca**, etc. At places on the membrane, there are minute pores (diameter approximately 8Å) surrounded by protein molecules.

Recently it has been revealed that instead of being rigid and non-deformable, the cell membrane is a fluid dynamic structure made up of lipid (phospholipid) and proteins (globular proteins). In 1972, Singer and Nicolson of California described it as the lipid-globular protein mosaic model or fluid mosaic model. According to this model, instead of a continuous layer of protein on the two surfaces of the membrane, there is a discontinuous mosaic of globular proteins contained in a phospholipid bilayer matrix. As the phospholipid is in fluid form, the proteins are randomly distributed and relatively free to move. All living membranes do not have the same chemical composition and protein-lipid ratio.

Structurally, the membrane proteins are of two types-extrinsic (or peripheral) proteins and intrinsic (or integral) proteins. The extrinsic proteins are associated with the membrane suface, entirely outside the lipid bilayer and they are soluble and readily dissociable from the membrane. The intrinsic proteins are relatively insoluble and dissociate with difficulty. Some of the intrinsic proteins are partially embedded in and partially protruding from the lipid bilayers while the others penetrate through the entire thickness of the membrane.

Functionally, the membrane proteins are of three types-structural proteins (that form the backbone of the membrane), carrier proteins or transporters or permeases (that help in transport of molecules across the membrane) and enzyme proteins or receptor proteins (that are catalytic in function). The lipid bilayer provides the permeability barrier.

Functions of cell membrane:

- [1] It gives the shape of the cells, especially the animal cells in which it is the only covering that forms the cell boundary.
 - [2] It gives origin to membrane bound cytoplasmic organelles.
- [3] It separates the protoplasm from the extracellular fluid so as to maintain the individual identity of the cells and protects the cytoplasmic organelles.
- [4] In animal tissues, the cell membrane forms linkages or places of close contact between the adjacent cells. This helps to maintain structural and functional integrity of the tissues and organs.
- [5] It maintains the excitability (i.e. capacity to respond to a stimulus) of the living cells. Some of the proteins present in the cell membrane act as chemical or molecular receptors that are specifically sensitive to regulatory chemical agents such as hormones, neurotransmitters etc. For this reason, these chemical agents can regulate the function of specific target cells.
- [6] The cell membrane acts as a medium of exchange (or transport) of materials between protoplasm and extracellular fluid. It works as a semipermeable membrane that allows passage of materials selectively and differentially in either direction. Hence, the cell membrane is considered as a selectively permeable membrane.

2.9.1. MEMBRANE TRANSPORT

The transport mechanism across the cell membrane may be of two types-[1] passive transport and [2] active transport.

[1] Passive transport: It is a process by which transport of materials takes place across the cell membrane without expenditure of energy (ATP), and it is governed by the concentration gradient of the material between the two sides of the membrane. It may or may not involve carrier molecules of the membrane (or the membrane transporters).

In passive transport, a material moves from the side of its higher concentration to the other, i.e. in favour of the gradient or down the gradient. There are two types of passive transports—diffusion and osmosis (these will be discussed in the next chapter). When a material e.g. O₂, ions, water, etc. is passively transported into the cell from outside (extracellular fluid), the process is called passive absorption. Conversely, if something (e.g. CO₂, waste product, etc.) is expelled out of the cell passively, the process is called excretion.

[2] Active transport: It is an energy (ATP) dependent process of transport of materials across the cell membrane. This process is generally mediated by certain carrier molecules present in the membrane. It does not depend on the concentration gradient and may even take place against the gradient (i.e. from lower to higher concentration). Entry of a substance into the cell by this process is known as active absorption; example—intake of glucose, amino acids etc. by the cells. Conversely, the porcess of expulsion of a material from the cell by expenditure of energy is called secretion; example—secretion of HCl by the oxyntic cells of stomach, secretion of H⁺ by the renal tubular cells, etc.

• Membrane transporters : Uniport, Symport and Antiport :

The carrier molecules present in the cell membrane for transport of materials across the membrane are protein in nature and they are called membrane transporters. Such

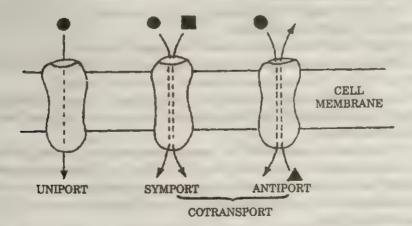


Fig. 2.12: The transport proteins of the cell membrane: uniport, symport and antiport.

transporters are required for a special type of passive transport called facilitated diffusion as well as for most of the active transports. Those carrying out active transport are referred to as pumps. The membrane transporters are very much specific in function

and each of them carries out the transport of specific material or materials across the membrane. Depending on the nature of their transport function, the membrane transporters are of the *three types* uniport, symport and antiport.

Uniports are those carrier proteins which transport only one substance in one

Symports are those carrier proteins that transport two substances at a time in the same direction.

Antiports are those carrier proteins that transport two substances simultaneously but in opposite directions *i.e.* they carry out exchange of one substance for another. Such transport mechanisms are called *countertransport*

Symports and antiports are together grouped as *cotransports* because they transport two substances simultaneously.

• Special types of carrier-independent active transports :

In addition to the above mentioned carrier mediated active transport, special mechanisms of active transport e.g. phagocytosis, pmocytosis etc. are seen in certain cells. These mechanisms do not require membrane bound carriers but require energy. The energy is required for contraction of microfilaments (actin and myosin) present in the peripheral cytoplasm, which causes the plasma membrane to invaginate for these processes. The energy dependence of these mechanisms is shown by the fact that during phagocytosis by leucocytes, glycogen breakdown, glucose uptake and O₂ consumption, all are increased. These mechanisms are as follows:-

cell), that is to say uptake or engulfment of solid particles by living cells. In this process, when a solid particle (macromolecule) comes in contact of a cell membrane, the latter invaginates to form a vesicle that surrounds the particle. Then the particle enveloped by the membranous vesicle, is incorporated within the cell by fusion of the cell membrane. The engulfed food vesicle (or food vacuole) is called phagosome. Engulfing of very small colloidal particles by this process is called ultraphagocytosis.

Example-phagocytosis of bacteria by the white blood cells, entry of proteins into the cells, etc.

[2] Pinocytosis: The meaning of this term is drinking of cells (Gr. pinein = to drink, kytos = cell). This is more or less similar to phagocytosis but the difference is that, in pinocytosis, a fluid is ingested by the cell. In this process, the cell membrane invaginates to form a narrow channel. The extracellular fluid enters within this

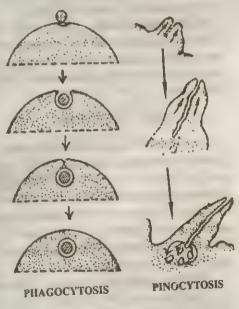


Fig. 2.13: Diagrammabe representation of phagocytosis and pinocytosis

pinocytic channel and from the inner end of the channel small fluid containing vesicles are pinched off one by one into the cytoplasm. These fluid containing vesicles are called pinocytic vesicles or pinosomes. A pinocytic mechanism involving formation of very small vesicles is called micropinocytosis. Example–feeding of Amoeba, absorption of certain materials in intestine, etc.

- [3] Endocytosis and Exocytosis: The process of entry of a substance into the cell by phagocytosis or pinocytosis is called **endocytosis**. The reverse process is known as **exocytosis**; example secretion of zymogen granules by the cells of the digestive glands, release of neurotransmitters from the nerve endings, egestion of waste matters from the cells, *etc*.
- [4] Emeiocytosis (or Reverse pinocytosis): It is the opposite of pinocytosis. It is also called 'vomiting of cells' (emesis = vomiting; cytos = cell) in which a cell expels something in fluid form; thus it is exocytosis of a fluid. In this process, the membrane covering of a vacuole or secretory vesicle fuses with the membrane and the fused portion ruptures to extrude the contents of the vacuoic or vesicle, leaving the cell membrane intact. Example-secretion of zymogen granules by the cells of digestive glands and release of neurotransmitters from the nerve endings.
- [5] Podocytosis (or Cytopemphis) and Transcytosis: It is the process of transport of materials across a cell. In this process, molecules are engulfed into the cell at its one surface by endocytosis and the vacuole containing the engulfed material moves across the cell to discharge its contents onto the opposite surface of the same cell by exocytosis. Thus, it is a combination of endocytosis and exocytosis at the opposite borders of the same cell. This phenomenon is commonly seen in renal tubular cells and intestinal epithelium during absorption of materials from tubular or intestinal lumen to blood.

Transcytosis is a similar term which indicates transport of fluid across a cell. This is seen in capillary endothelial cells.

[6] Rhopheocytosis: It is a process of hulk transport in which small quantities of cytoplasm together with the inclusions are transferred from one cell to another. It is seen in bone marrow where cytoplasmic fragments containing ferritin granules are transferred from reticulo-endothelial cells to erythroblasts during maturation of red blood cells.

2.9.2. CELL JUNCTIONS

Cell junctions are specialised regions of firm intercellular connections between the plasma membranes of adjacent cells. These are observed only in some animal tissues and are formed by interaction, attachment and modification of some areas of the adjoining plasma membranes. Cell junctions have three major functions—(i) they provide mechanical support to the tissues by holding the cells together; (ii) they help in communication between the cells and (iii) they may form an impermeable barrier between the interstitial space and an epithelial surface (lumen). Cell junctions are of the following four major types:

[1] Tight junction or Zonula occludens (Occlusion zone):

Tight junctions are specially differentiated regions, where the lateral plasma membranes of two adjacent cells fuse together at series of points containing sealing strands, which form lines of attachment. The sealing strands are made up of rows of integral membrane proteins contributed by each plasma membrane. This type of junction

is found in between the brush bordered epithelial cells of intestine and renal tubules. It is located at the apical region of the cells just below the microvilli.

Tight junctions seal (or occlude) the intercellular space and prevent the passage of substances across the epithelium. Thus, such impermeable junctions form a barrier between the two sides of the epithelial lining, so that the materials absorbed across the epithelial cells at the expense of energy may not leak back into the lumen of the intestine or renal tubule. Such junctions also help to prevent random movement of

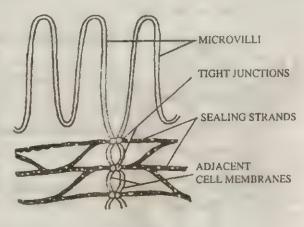


Fig. 2.14: Light junction

the integral proteins within the membrane.

- [2] Desmosome: Desmosomes are cell junctions for mechanical adhesion between the cells. Desmosomes are of two types belt desmosome and spot desmosome.
- (a) Belt desmosome—It is also called zonula adherens or terminal bar or intermediary junction. It is found at the interface between the columnar epithelial cells, just below the tight junctions. It is a band like zone, that runs parallel to the free surface

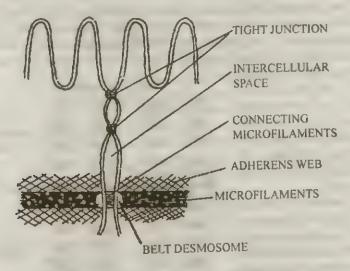


Fig. 2.15: Belt desmosome.

of the cells. It consists of two actin-made microfilaments each of which is located on the cytoplasmic surface of each membrane. These actin filaments are joined by connecting microfilaments running across the intercellular space. The belt desmosomes remian connected with the terminal web (or adherens web) present on either side of the junction.

(b) Spot desmosome—It is also called *macula adherens*. It is a disc-shaped spot or area of contact between the adjacent cell membranes. It consists of a disc-shaped,

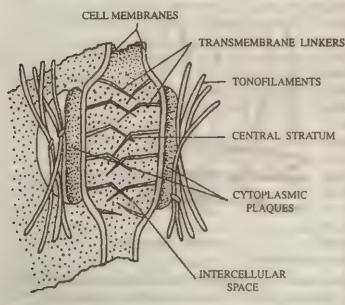


Fig. 2.16: Spot desmosome.

dense, protein- made cytoplasmic plaque under TRANSMEMBRANE LINKERS each membrane. These plagues are joined by fine filaments, the transmembrane linkers, that traverse the intercellular space. Numerous keratinmade filaments called 'tonofilaments' remian attached to the cytoplasmic plaques. Spot desmosomes are found in the epithelial cells of uterus, vagina and epidermis of skin to support the cells against severe mechanical stress.

In the basal border of some epithelial cells,

structures similar to half desmosomes are observed. These are called hemidesmosomes, which firmly bind the epithelial cells with the underlying basement membrane.

[3] Gap junction (or Nexus): A gap junction is a disc-shaped area of close intercellular contract having a narrow intercellular space between the two adjacent plasma membranes. At this junction, each membrane contains several protein molecules called 'connexon', which are arranged in such a way that they form an intercellular

pipe (or channel) through which various small molecules and ions can pass from one cell to the next. Thus, the gap junctions provide a pathway for communication between the adjacent cells.

Gap junctions are found in cardiac and smooth muscles (but not in skeletal muscle), liver cells, embroyonic cells etc. In electrically excitable tissues such as cardiac and smooth muscles, this type of

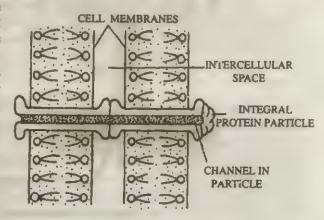


Fig. 2.17 : Gap junction.

junction facilitates spreading of impulse from one cell to another. In other tissues like liver, embroynic tissues etc., the gap junctions provide a system, by virtue of which the adjacent cells can share a common pool of metabolites and ions that pass freely from one cell to another.

[4] Interdigitated junction or Intercalated (or Intercalary) disc:

These are found in cardiac muscle cells (or fibres). These are areas of extensive cell contact running transversely between the two adjacent fibres arranged in longitudinal series. In such junctions, the adjacent plasma membranes are thrown into folds and the evaginations of one membrane fit into the invaginations of the other. Such junctions keep the cells tightly adhered and increase the surface area for exchange of materials.

2.9.3. CELL ADHESION MOLECULES (OR CAMS)

Besides the cell junctions, there are some protein molecules in between the tissue cells for binding the cells together. These protein molecules are called **cell adhesion** molecules or CAMs. The CAMs of adjacent cells bind together to give stability to the tissue. The CAMs include proteins like cadherins, integrins, selectins etc.

2.9.4. CELL COAT OR GLYCOCALYX

Cell coat is an external covering around the plasma membrane of some animal cells. It is also called *glycocalyx* because it is made up of glycoproteins or mucopolysaccharides. The cell coat is a kind of secretory product of cytoplasm that undergoes an active turnover.

The cell coat has several functions :-

[1] It gives mechanical protection to the plasmalemma.

[2] It may take part in diffusion and filtration processes and thereby makes a microenvironment for the cell.

[3] In case of the intestinal cells, the cell coat on the surface of the microvilli contains enzymes for digestion of carbohydrates and proteins.

[4] It helps in recognition of molecules by the cells.

[5] It gives antigenicity to the cells like RBCs and other cells.

• How would you demonstrate the semipermeable or selectively permeable nature of the cell membrane?

A few beet-root cylinders of equal size are taken out with the help of a cork borer and washed thoroughly with water to remove the betacyanine pigment of the damaged cells. Then one or two beet-root cylinders are placed into two beakers containing pure water and hypertonic solution respectively. After some time, it will be noted that the beet-root cylinders placed in pure water have become more turgid due to endosmosis (entry of water molecules into the cells), while those beet-root cylinders placed in hypertonic solution have become loose due to exosmosis (coming out of water from the cells). However, the colour of the water in both the beakers remains unchanged.

These observations clearly show that the cell membrane of beet-root is of semipermeable (or selectively permeable) nature because it has allowed only water molecules to pass through it but not the betacyanine pigments.

• How would you demonstrate that cell membrane is a living structure?

That the intact cell membrane is a living structure can be demonstrated by an experiment based on the fact that a living membrane is selectively permeable and it acts as a barrier, while a dead membrane is totally permeable and it cannot act as a barrier. If some thoroughly washed slices of beet-root are placed in a beaker containing water at room temperature, it will be seen that the colour of the water will remain unchanged. This indicates that the intact membrane acts as a barrier and it does not allow the betacyanine pigments of the beet-root cells to pass out. On the other hand, if some thoroughly washed beet root slices are placed in a beaker containing boiling water, the colour of the water turns purple. It indicates that, as the cell membrane is

rendered dead by boiling water, it has become permeable and the betacyanine pigment has come out of the cells.

What are microvilli?

In some animal cells, the cell membrane is thrown into finger like folds; these are called microvilli. These are found in the epithelial cells of renal tubule and intestinal mucosa. They increase the surface area of the cell membrane.

• What are caveoli?

Caveoli are small pits on the cell surface formed by invagination of the cell membrane. They help in the intake or secretion of materials by the cells.

• What is meant by "unit membrane of Robertson"?

Robertson suggested that all the living membranes including plasmalemma and the membranous covering of the organelles have a basically similar trilamellar structure made up of protein-lipid-protein (P-L-P). This P-L-P structure is referred to as "unit membrane of Robertson."

2.10. Cell Wall

Definition: The thick and rigid, nonliving covering present just outside the plasma membrane of plant cells is called cell wall.

Cell wall was discovered by Robert Hooke in 1665 while he observed cells in the sections of cork.

Occurrence: Cell wall is not found in animal cells; it is present in all plant cells except the gametes and the cells of a few lower plants.

Origin: Endoplasmic reticulum and Golgi body play an important role in the formation of cell wall. During cell division, after the nuclear division is complete, fragments of endoplasmic reticulum and Golgi body called phragmoplasts become arranged in a row at the equatorial region (in between the two daughter nuclei). These then fuse to form a continuous membranous structure called cell plate. The cell plate secretes pectin and gives rise to the middle lamella. Finally, some complex chemical compounds produced within the cell (protoplasm) as a result of metabolism are deposited on the intracellular side of the cell plate (middle lamella).

Structure: The cell wall may be comparatively thinner in some cells e.g.

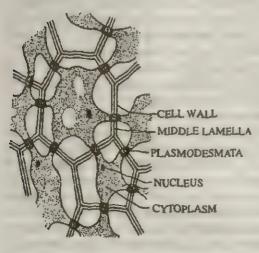


Fig. 2.18: Plasmodesmata

parenchyma cells, or thick in others e.g. the cells of sclerenchyma and vascular tissue. It may be either smooth or unevenly thickened. There are minute pores on the cell wall through which cytoplasmic continuity is established between the adjacent cells. These cytoplasmic bridges are called plasmodesmata (sing. plasmodesma). In matured cells, the cell wall is composed of three layers that are formed sequentially from outside inwards as follows: [1] middle lamella, [2] primary cell wall and [3] secondary cell wall.

[1] Middle lamella: The thin layer

of jelly-like viscous intercellular matrix present in between two adjacent cells is known as middle lamella. It is a common layer between the adjacent cells that binds them like a cementing material. It is a colloidal material composed mainly of **pectin** (a complex carbohydrate) and some amount of protein. This layer is elastic and is formed first during cell division.

[2] Primary cell wall: The layer just beneath the middle lamella is called primary cell wall. In fact, this is the outermost layer of an individual plant cell. It is formed after

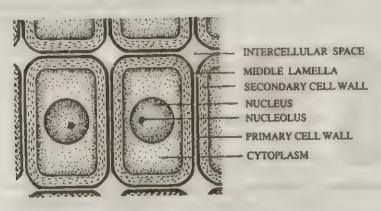


Fig. 2.19: Organisation of cell wall.

the formation of middle lamella by deposition of protoplasmic secretory materials on the inner side of the middle lamella. It is $1-3~\mu m$ thick; the thickness gradually increases

with growth of the cell and after completion of primary cell wall formation, the cell does not increase in size. This layer is thin, plastic and permeable. It is composed of cellulose mainly. Small amounts of pectin, lignin and suberin are also present in it. In the epidermal cells of leaves and stem, the primary cell wall contains cutin or cutin wax that renders it waterproof so as to prevent excess water loss by evaporation.

[3] Secondary cell wall: The thick and rigid layer beneath the primary cell wall (i.e. in between the primary cell wall and plasmalemma) is known as secondary cell wall. This layer is deposited on the primary cell wall (inside it) after the growth of the cell has ceased. The secondary cell wall is generally seen in dead cells and vascular tissues. In the cells of meristematic tissue and cambium, this layer is absent; naturally primary cell wall is the only layer present inside the middle lamella of these cells. The

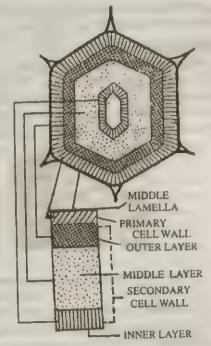


Fig. 2.20: Different layers of cell wall

secondary cell wall is also made up of cellulose mainly; however, some amount of other complex materials e.g. hemicellulose, pectin, lignin, etc. are also present in it.

In some plant cells, there is an additional layer beneath the secondary cell wall; this is known as **tertiary cell wall** and is made up of **xylan** (a polysaccharide made up of the pentose sugar xylulose). The cell walls of certain fungi and yeast are composed of **chitin**.

Ultrastructure (molecular structure) of cell wall:

Cellulose, the chief constituent of cell wall is a polysaccharide made up of numerous (about 3000) glucose units. Nearly 100 cellulose chains become arranged side by side

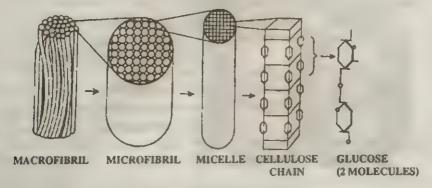


Fig. 2.21: Ultrastructure of cell wall.

(parallely) to form very minute bundles called **micelle**. About 20 micelle assemble in the same way to form a **microfibril**. In the primary and secondary cell walls, the microfibrils remain arranged in bigger bundles called **macrofibrils**. The spaces in between the microfibrils are filled up with pectin, hemicellulose, lignin, suberin *etc*.

Thickening of cell wall:

In some plant cells like those present in the vascular tissue (xylem cells and vessels) of the woody parts of the plants, during the formation of secondary cell wall, its constituents are deposited unevenly on (inside) the primary cell wall. As a result, the cell wall becomes peculiarly thickened at places giving rise to development of various patterns of characteristic ornamentations as follows:—

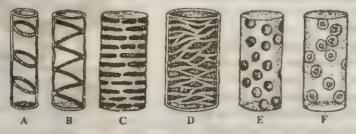


Fig. 2.22: Thickening of cell-wall · A Annular, B Spiral, C Scalariform, D Reticulate, E & F -Pitted (F-Simple, F-Bordered)

- [1] Annular-In this case, the materials of secondary cell wall are deposited in a ring like fashion leaving a definite gap in between the rings.
- [2] Spiral-In this type, the thickening of secondary cell wall takes place in the form of a spiral band encircling the cell.

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[3] Scalariform-This type of thickening is due to deposition of materials in the form of transverse bands at regular intervals. Thus, the cell wall acquires a ladder-like appearance.

[4] Reticulate-In this type, the thickening is irregular and looks like a network.

[5] Pitted-If the secondary wall materials are deposited uniformly more or less all over the primary wall leaving many small roughly circular or oval areas, the unthickened areas look like minute holes called pits and this type of thickening is known as pitted.

Pits generally occur in pairs at the same lavel on either side of the common cell wall between two adjacent cells. When a pit is not paired, it is called a blind pit. Pits are made up of the following parts: (a) Pit chamber or pit cavity—the actual hollow space or hole within the secondary wall; (b) Pit aperture—an opening through which the pit cavity is connected with the interior of the cell; (c) Pit membrane or closing membrane—the separating wall being composed of middle lamella and the primary cell walls present between the two adjacent pits of a pit pair.

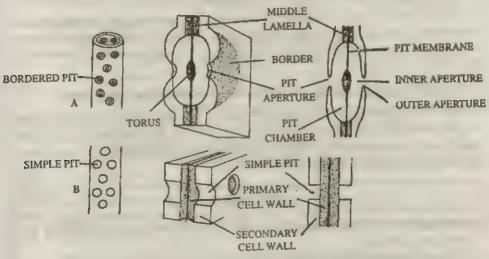


Fig. 2.23 : Structure of pit. A. Bordered, B.-Simple
Lett external structure , Middle three dimensional L.S.; Right two dimensional L.S.

Pits may be either simple or bordered. In bordered pits, the edge of the pit aperature is specially thickened to form a ring-like border. Simple pits do not have such border. In some cases, the border of the pit is excessively thickened, so as to form a canal called pit canal, that connects the pit cavity with the interior of the cell. The pit canal communicates with the interior of the cell at one end and pit cavity at the other end by two apertures called outer aperture and inner aperture respectively. In most of the bordered pits, the central part of the pit membrane swells up like a disc, which is called torus. While th cell is increasing in size, due to stretching of the primary cell wall, some holes are formed in it at places; these are called primary pit fields through which plasmodesmata connect the adjacent cells.

Functions of the cell wall:

- [1] As the cell wall is rigid, it protects the cell from external injuries.
- [2] It gives a definite shape of the cell.
- [3] It gives mechanical support to the cell. Particularly in the woody parts of the

plants, the cell wall becomes hard due to deposition of lignin and imparts rigidity and strength to the plant.

- [4] Being permeable to water and salts, the cell wall allows entry and exit of these materials to and from the cells.
 - [5] It helps to maintain intercellular connections through plasmodesmata.
- [6] In the epidermis of various parts of the plants, the cell wall becomes water proof due to deposition of cutin and suberin. This helps to reduce evaporation and water loss from the plant.

• Why cell wall is called exoskeleton of plant cells?

The cell wall is considered as the exoskeleton of plant cells because it is an external rigid structure of the plant cells that protects the cells from external injuries, gives a shape to the cells and provides mechanical support to the cells.

• What are the special features of bacterial cell wall?

The cell wall of bacteria is made up of mainly **mucopeptides** and **peptidoglycans**, containing sugars and aminosugars. In gram positive bacteria, the cell wall additionally contains RNA while in gram negative bacteria, the cell wall contains lipids instead of the RNA.

• Difference between the cell wall of bacteria and higher plant cells :

The chief constituents of bacterial cell wall are mucopeptides and peptidoglycans. In some bacteria (gram positive bacteria), the cell wall also contains RNA. On the other hand, the cell wall of higher plant cells is made up of carbohydrates like cellulose, pectin, lignin etc. and it does not contain RNA.

REVISION

Plasmalemma or plasma membrane—The lipoprotein membrane covering the cytoplasm of the cell.

Cell wall—Rigid exoskeletal structure enclosing and protecting the contents of plant and bacterial cells.

Plasmodesmata-The cytoplasmic bridges between the adjacent plant cells.

Cell plate—The primitive partition formed between the two daughter nuclei at the equatorial region of a plant cell after nuclear division, from which the new cell wall originates.

2.11. Cytoplasm: [Gr. kytos = hollow; plasma = form]

Definition: The protoplasmic contents of a cell excepting the nucleus is called cytoplasm.

or

The semiliquid and granular part of the cell (or protoplasm) that remains extended from plasma membrane to nuclear membrane is known as cytoplasm.

Cytoplasm is a colloidal material. It is composed of three distinct types of components—(i) Cytoplasmic matrix, (ii) Cytoplasmic organelles and (iii) Cytoplasmic inclusions or Ergastic substances.

2.12. Cytoplasmic Matrix: [L. matrix = womb]

Definition: The fluid ground substance of cytoplasm, in which the organelles and inclusions remain suspended is called cytoplasmic matrix.

Structure: This transluscent fluid part of cytoplasm is also called hyaloplasm. It is composed of water and various inorganic and organic materials e.g. salts, sugars, amino acids, proteins, enzymes, etc. that remain either in dissolved (solutes) or in dispersed (colloidal particles) state. This part of cytoplasm is also known as cytosol or soluble fraction of cytoplasm because it is separated as the remaining supernatant after precipitation of all the organelles by centrifugation during cell fractionation. It contains soluble RNA or transfer RNA (sRNA or tRNA). The peripheral narrow part of cytoplasmic matrix which is relatively transparent, non-granular, more viscous and rigid is called ectoplasm (or plasmagel or cortex of cytoplasm), whereas the inner granular and less viscous part of it is called endoplasm (or medulia of cytoplasm). The thin layer of cytoplasm that surrounds the vacuoles is known as tonoplasm.

Functions of cytoplasmic matrix:

[1] It carries the cytoplasmic organelles and inclusions.

[2] It imparts the colloidal properties of protoplasm e.g. sol-gel transformation, viscosity changes, intracellular movements such as cyclosis, etc. Due to such movements of cytoplasm, various substances are carried from one place to another within the cells.

[3] It gives origin to the fibrillar components and microtubules in certain cells, myofibrils in muscle cells, keratinised tonofilaments in epithelial cells, etc.

[4] It maintains the internal milleu of the protoplasm.

[5] It contains the enzymes responsible for some **metabolic processes** e.g. glycolysis, fatty acid synthesis, etc.

2.13. Cytoplasmic Organelles: [Gr. organon = instrument]

Definition: The living structures of cytoplasm that remain dispersed in the matrix are called cytoplasmic organelles.

Most of these are unit membrane bound structures. Unlike the prokaryotic cells, several such membrane bound organelles are found in eukaryotic cells; these are mitochondria, endoplasmic reticulum, ribosome, Golgi body, microtubules, centrosome, lysosome, plastid and vacuole. Each organelle is responsible for some important functions of the cell.

2.14. Mitochondria: [Sing. Mitochondrion; Gr. mito = fibril, chondrion = granule]

Definition: The rod-like, filamentous, spherical or oval, double membrane bound cytoplasmic organelles of eukaryotic cells, which are concerned with cellular respiration are called mitochondria.

Mitochondria were first observed by **Kolliker** (1850) in striated muscle cells as granular structures. **Flemming** (1882) demonstrated mitochondria as thread-like bodies and called them *fila*. **Altman** (1892) described them as *bioplasts*. Finally the name mitrochondria was introduced by **Benda** (1897) for these organelles. The presence of mitochondria in plant cells was first noticed by **Meves** (1904) in *Nymphaea*. **Kingsbury** (1912) first suggested that mitochondria are the sites for cellular respiration.

Distribution and Number: Mitochondria are found in all living cells except the prokaryotic ones. However, the bacterial cells possess mesosomes as a substitute of mitochondria. The mature mammalian RBCs do not contain mitochondria. Generally, these are uniformly distributed throughout the cytoplasm and they move (change their position) singly or in groups. In certain cases, they remain accumulated at a particular part of the cell. For example, during cell division, they accumulate around the spindle; in muscle fibres, they are located close to the contractile elements; in adipose tissue cells, due to excessive fat deposition, mitochondria along with other organelles are pushed towards the periphery of the cells; in renal tubular cells, these are present near the basment membrane. Generally, mitochondria accumulate in greater numbers in that part of a cell where energy production is needed.

The number of mitochondria varies from cell to cell; plant cells contain fewer mitochondria than animal cells. The number of mitochondria in a cell is generally proportional to its energy requirement. The cells concerned with active (energy requiring) processes such as secretion, contraction etc. contain large number of mitochondria. Conversely, those cells which do not require much energy (e.g. squamous or stratified epithelial cells) possess smaller number of mitochondria. The cell of Microsterias, an unicellular alga, contains only one mitochondrion, whereas the cell of the giant protozoa called Chaos chaos possesses largest number of mitochondria, about 500,000. In a cell of higher plant or animal, the number may range between a few to several thousands.

Origin: Mitochondria originate from the pre-existing mitochondria within the cell. However, it is believed that mitochondria may also originate from plasma membrane or endoplasmic reticulum or nuclear membrane. The life span of mitochondria is only 5-10 days; obviously, they are continuously produced and destroyed within the cells.

Ultrastructure: Mitochondria vary in shape and size. Typical mitochondria are generally rod-shaped, having lengh 1-4 µm and breadth 0.2-1.5 µm. In some cases, these may be spherical or oval or filamentous (length upto 12 µm).

Mitochondria are closed sac-like structures covered by two membranes, each of which is a trilamellar lipoprotein (P-L-P) unit membrane very similar to the plasma

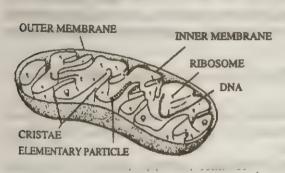


Fig. 2.24: Structure of mitochondrion.

membrane. These two membranes, called outer membrane and inner membrane, form two chambers in mitochondria. The narrow space between the two membranes is called outer chamber or intermembranal space or perimitochondrial space, whereas the central wider space enclosed by the inner membrane is called inner chamber or inner membrane space. The outer chamber is filled

with a watery fluid whereas the inner chamber is filled with a homogeneous, granular, dense, jelly-like material called mitochondrial matrix.

The inner membrane is thrown into folds that form finger like projections called mitochondrial crests or cristae mitochondriales or in short cristae (sing. crista) within

the inner chamber. The cavity of the cristae is called intracristae space, which is continuous with the outer chamber. The cristae divide the inner chamber into a few

incompletely partitioned subchamber between which a continuity is maintained by the matrix. The cristae contain various enzymes responsible for the function of mitochondria. Thus, they help to increase the effective functional area of mitochondria considerably. For this reason, the mitochondria of cells that remain continuously active, possess large number of cristae; example—cardiac muscle. The shape and structure of cristae vary in mitochondria of different cells. For example, in rat liver cells, these are septum or plate like;

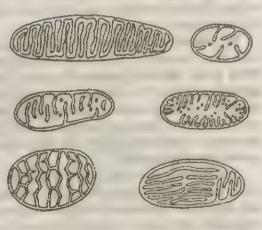


Fig. 2.25 : Different types of eristae.

in plant cells, these are tubular; and so on.

The inner membrane and the cristae contain numerous small 'tennis racket shaped'

The inner membrane and the cristae contain numerous small 'tennis racket shaped' particles, that project towards the matrix. These are called Fernandez Moran subunits*

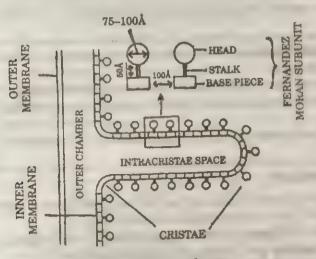


Fig. 2.26: Ultrastructure of cristae

or elementary particles or oxysomes. These particles are arranged in series and there is a definite space of about 100 A between two adjacent particles. Each particle is made up of three parts-base piece, stalk and head. The spherical head called F. particle, which remains attached to the base piece by the stalk. The base piece remains deeply embedded within the inner membrane.

Chemical composition of mitochondria: Mitochondria are composed of protein (60-70%), lipid (25-30%) and RNA (0.5%). Majority of proteins are enzymes while the remaining ones are structural proteins. Recently it has been revealed that the mitochondrial matrix contains ribosomes of relatively smaller size called mitoribosomes (55S type), DNA threads and some granules; one type of granule contains calcium phosphate.

^{*}These were so named after Humberto Fernandez Moran who along with his co-workers first observed these particles under electron microscope.

Functions of mitochondria:

Due to the presence of various metabolic enzymes in them, mitochondria function as one of the most important sites of cellular metabolism. Metabolic processes occurring in mitochondria are as follows:—

[1] Catabolic processes: Majority of the mitochondrial enzymes are concerned with final oxidation of foodstuff in cellular respiration. Mitochondria are the sites of TCA cycle, electron transport system (or biological oxidation) and oxidative phosphorylation. For details of TCA cycle, electron transport system and oxidative phosphorylation see chapter-9. Through these processes, energy is released by oxidation of foodstuff and stored in the form of ATP. Energy required for various biological processes is derived from ATP. For this reason, mitochondria are considered as the power house of the cell.

Mitochondria also carry out the oxidation of fatty acids (β -oxidation) and amino acids. In this context, it should be mentioned that TCA cycle, β -oxidation of fatty acids and oxidation of amino acids take place in themitochondrial matrix because the enzymes responsible for these are present in this part. On the other hand, electron transport and ATP production by oxidative phosphorylation take place in the cristae; the enzymes for electron transport are present in the inner membrane of cristae and those for ATP synthesis are located in the F, particles.

- [2] Anabolic processes: Mitochondria carry out two types of anabolic processes—
 (i) synthesis of fatty acids and (ii) production of DNA, RNA and some proteins. The proteins synthesised in mitochondria are mainly enzymes, that catalyse the metabolic reactions occurring in it.
 - Mitoplast and Chondriosphere: These two terms are related to certain modifications of the mitochondria.

Mitoplast is a mitochondrion from which the outer membrane has been stripped. Thus, a mitoplast contains the inner membrane and the matrix. It is not a natural cell organelle.

Chondrosphere is a large body formed by fusion of mitochondria. It is a degenerative structure.

2.15. Endoplasmic Reticulum

Definition: The membrane bound irregular, network-like vacuolar system present in the cytoplasm of eukaryotic cells is called endoplasmic reticulum.

In 1945, Porter, Claude and Fullam first observed this organelle in fibroblast cell. Subsequently, Porter and Kallman gave its name 'endoplasmic reticulum' in 1952.

Distribution and Number: Endoplasmic reticulum (ER in short) is found in all eukaryotic cells except ovum, mammalian matured RBC, fungi and some lower plant cells. It extends from the cell membrane to the nuclear membrane but it remains more concentrated in the endoplasm than in the ectoplasm, and hence it is so named. The size and number of ER in a cell depends on the size of the cell.

Origin: The exact origin of ER is uncertain but because of its intimate relationship with cell membrane and nuclear membrane, ER is believed to originate from these membranes.

Ultrastructure: ER is made up of a network of different types of membrane bound vacuoles or canaliculi that remain connected with the plasmalemma at one end and

nuclear membrane at the other end. The membranous covering of the canaliculi is a trilamellar (P-L-P) unit membrane like the plasmalemma but it is comparatively less

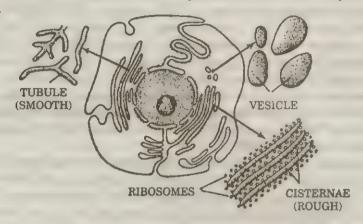


Fig. 2.27: Different parts of endoplasmic reticulum.

thick. Some authorities claim that the cell membrane invaginates at places to form canaliculi which become highly folded and branched to form a network and finally end around the nuclear material. The nuclear ends of these canaliculi come close together and form the nuclear membrane. As minute gaps are left in between the adjacent nuclear ends of the ER, the nuclear membrane becomes porous.

Three types of structures are observed in the ER :-

- [1] Cisternae (sing-cisterna) or Lamellae (sing. lamella): These are wide and flat membrane bound cavities that are parallely arranged like selves. The adjacent cisternae remain communicated. Numerous ribosomes are attached to their surface membrane. So the cisternae are rough surfaced structures.
- [2] Tubules: These are elongated and branched tube-like structures devoid of ribosomes on their surface; hence, they have a smooth surface.

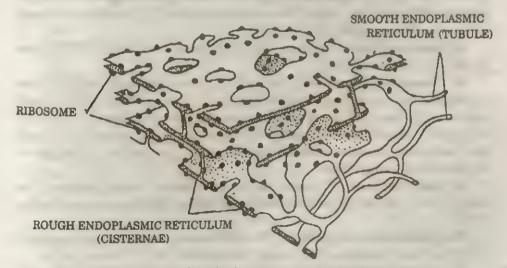


Fig. 2.28: Three dimensional structure of endoplasmic reticulum.

[3] Vesicles: These are spherical or oval sac-like cavities.

The tubules remain connected to both cisternae and vesicles, thereby giving a reticular appearance of the organelle. Structurally, the ER may be of two types rough and smooth. Those containing ribosomes on their surface are called granular or rough endoplasmic reticulum (RER) or ergastoplasm, whereas those devoid of ribosomes are called agranular or smooth endoplasmic reticulum (SER). Obviously therefore, the RER is made up of cisternae (that contain ribosomes) mainly, whereas the SER is mainly composed of tubules (devoid of ribosomes). The attachment of ribosomes to the ER membrane is mediated by special types of glycoproteins called ribophorins. Ribophorins are of two types ribophorin I and ribophorin II that are present in the RER membrane. They have specific affinity to ribosomes, and bind them with the RER Ribophorins are not found in SER.

Ribosomes are concerned with protein synthesis, hence in the cells that are engaged in protein synthesis and secretion (e.g. cells of liver, pancreas ete) the RFR is highly developed. On the other hand, the cells that do not synthesise much protein (e.g.) evolutions of testis, adipose tissue cells, oxyntic cells of stomach, ete) contain SFR mainly. In a cell, the SFR and RFR freely communicate with each other

Chemical composition: As the FR is a membranous organelle, its chief constitutents are lipid and protein. The lipids constitute 30-50%, of which the major portion is lecithin and cephalin type of phospholipids. The ribosomes present in RER are made up of RNA and protein.

Functions of ER:

[1] Mechanical support: The FR forms a network like structure in the cytoplasm that gives mechanical support to the cytoplasmic matrix

[2] Formation of other organelles: FR helps in the origin of nuclear membrane, Golgi body and microbodies.

[3] Exchange of materials: The tubular network of FR is continuous externally with the cell membrane, and extracellular fluid (FCF) flows within it. Thus, the FR provides an 'intracellular circulatory system' that ensures a far greater surface of exposure of the cytoplasm to the extracellular environment. This facilitates exchange of materials between cytoplasm and ECF.

[4] Protein synthesis: Due to the presence of ribosomes in them, the RER functions as the site of protein synthesis.

[5] I ransport of information: The SER is especially important for transmission of impulse from the cell membrane into the interior of the cell. Particularly in muscle cells (muscle fibres), the SER is modified into sarcoplasmic reticulum which transmits the impulse received by the cell membrane (sarcolemma) to the contractile machinery for 'excitation-contraction coupling' (i.e. initiation of contraction in response to stimulation of a muscle fibre).

[6] Lipid synthesis: ER takes part in synthesis of various lipids a g tats (triglycerides), steroids, lipoproteins and phospholipids. This function is attributed to SER.

[7] Carbohydrate metabolism: The SFR is also believed to be involved in 'glycogenolysis' (breakdown of glycogen into glucose)

[8] Detoxication: The SER is probably concerned with detoxication of drugs and toxins.

It should be noted that out of the constant of the first three are common to bot. Bl R in $A \subseteq R$ is the sum of the constant of the proof of the constant of the constant of the proof of the constant of the constant

2.15.1 MODIFICATIONS OF FR. SOME SPECIALISED CELL STRUCTURES RELATED TO ER.

In some cell, the LR on when the theory is a standard accordance to expedience the control of the product of th

- (b) Sarcoplasmic reticulum: It is a model of from all SER to the lasterate dimension cells aboth skelle and can be of the time of a point in transmitted the product transmitted the major of the product transmitted the major of the product the muscle fibres. Thus, it links the exception of the product to the section of the product to the product of the product to the product of t
- (ii) Mixeloid body: It is also a most for 1 them of NER Constructing on a reclicitly of refina of treat It consists of a number of rightly placed exercises problem.
- (iii) Annulate lamellae: The care trace and exterior as the first possible represent an internal frate stage in the termation RTR. The property of double membraned fenestrated sheets arranged in tacks. Procare together with and embryonic cells mainly where the inetabolic activity is very both. Not alate him flac may contain ribosomes on their surface.
- (iv) Glycosumes: These are sphero fal structures contained by open and steround in liver cells where they help in allicones abraice. One is most are found to remain attached to the SER and are thought to be produced by most freation of the SER.
- (v) Microbodies: These are simple membrane bound small vesicular bodies to and in plant and animal cells. Microbodies are formed is diffatation of the LR and they may remain connected to the LR. These vesicular or small is contain certain oxidative enzymes. The function of microbodies is to restrict the enzyme contained in them and thereby the chemical reactions catalyzed by these inzymes in different resonance cell. Microbodies are distinguished into two classes peroxisomes and glyoxyxomes, depending upon the enzymes present at them.

Peroxisomes. These are microroshes containing on lative ergences as peroxidase catalase etc. that are related to formation and do traction of his free experioside ell. On The name peroxisome was given to this organelle because it is specifically conficient with metabolism of hydrogen peroxide. Peroxisomes are found in the cells of utimal and plant tissues like liver, ki his count state is averaged. In proceed leaves of the plants the peroxisomes jointly with charros lasts take part in photorespiration.

Glyoxysomes. These are plant microboshes containing entropy store, 'voxylate cycle hence they are so named. Glyoxysomes also contain crizylia of or provide and fatty acids. These enzymes and this the recoxysomes are mystyreful mineral, but of stored lipids by conversion of fats to carbot. Trates. These are found in oil rich, endo permitissues of seeds. Glyoxysomes may in fan germination of oil bearing social.

(vi) Microsomes: I) escare incroscopic particles obtained form, cen fractionation by differential centrification of trace bonose; rate: Farher increasing we altought to be a cell organistic concerne livity protein synthesis as it contains mention bound tibosomes. Actually, it is an artifact formed by again gation of RER. SER. Gol. body and trainents of passing membrane, and it is not be und in the intact cell as an organical.

Microscome 11 and not be cert and with an embadies because the microsomes are not natural cell structures, while the interobodies are natural cell structures.

2.16. Ribosomes

Definition: Ribosomes are small, granular, non-membranous structures that are made up of RNA and protein and concerned with protein synthesis.

In 1943, Claude first observed the presence of this organelle in a cell. Later Palade (1955) gave a detailed description of it and introduced its name. It is also called Claude's particles.

Distribution and Number: Ribosomes are present in both eukaryotic as well as prokaryotic cells. In the eukaryotic cells, these are found mainly attached on the outer surface of the rough endoplasmic reticulum. In addition, a few ribosomes of relatively smaller size are also present within mitochondria and plastids or freely scattered in the cytoplasmic matrix. The cytoplasmic and mitochondrial ribosomes are called cytoribosomes and mitoribosomes respectively. In the prokaryotic cells, due to the absence of the membranous organelles, ribosomes, remain freely scattered in the cytoplasm; these are called monosomes. Ribosomes may remain singly or in clusters. During rapid synthesis of proteins in a cell, a few ribosomes become joined together temporarily by means of mRNA to form a cluster called polyribosome or polysome. Polysomes are found in the cytoplasm of prokaryotic and eukaryotic cells as well as within mitochondria.

In eukaryotic cells, there are millions of ribosomes (1-10 million), the number is especially higher in cells that are engaged in protein synthesis. Prokaryotic cells like bacterial cells contain comparatively much smaller number of ribosomes (about 10,000 on an average).

Origin: In eukaryotic cells, ribosomes are formed by the joint action of nucleolus and cytoplasm. The ribosomal RNA (rRNA) is formed in the nucleolus. The protein of ribosome is produced in the cytoplasm and then carried to the nucleus where it combines with rRNA to form the subunits of ribosomes. These subunits are then transferred to the cytoplasm, where they are assembled into fully formed ribosomes.

In prokaryotic cells, the rRNA is formed by the DNA thread present in the nucleoid region; thus development of ribosomes wholly occurs in the cytoplasm (because such cells are devoid of actual nucleus).

Ultrastructure and Chemical composition: Ribosomes are spherical or oval bodies. Each ribosome is made up of two unequal subunits that remain bound to each

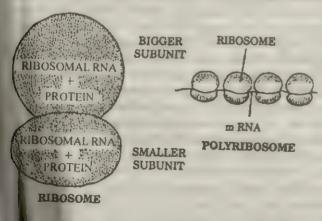


Fig. 2.29: Ribosome and polyribosome

other by magnesium ions. If the concutration of Mg²⁺ is reduced, the two subunits become dissociated and they associate again if the Mg²⁺ concentration is raised. Of these two subunits, the bigger one is spherical and the smaller one is oval Unlike other organelles, the ribosomes are not enclosed by a membrane. Ribosomes are composed of a special type of RNA

called ribosomal RNA or rRNA and histone (basic) protein. The proportion of rRNA and protein is roughly fifty-fifty (i.e. 1-1) in cukaryotes, whereas it is nearly 2.1 in prokaryotes.

All ribosomes are not equal in size. They are distinguished on the basis of their physical property of sedimentation coefficient (an index of how fast a particle sediments on ultracentrifugation) which is expressed by S unit (—Svedberg unit). The larger and heavier is a body, the more will be the sedimentation coefficient. Three types of ribosomes have been identified; these are designated as 80 S, 70 S and 55 S ribosomes. 80 S ribosomes are largest in size and are found in eukaryotic cells (both plant and animal cells); its subunits are 60 S and 40 S. 70 S ribosomes are relatively smaller and are found in prokaryotic cells, these are made up of 50 S and 30 S subunits. 55 S ribosomes are smallest, containing 35 S and 25 S subunits, these are found within mitochondria of mammalian cells. Ribosomes remain attached to FR by ribophorins through their larger subunits (60 S).

Function of ribosomes:

Ribosomes are concerned with protein synthesis. Ribosomes jointly with the mRNA form the template (platform or actual site) on which the amino acids are joined one after one by peptide bonds to form the polypeptide chain of the proteins.

Informosomes :

In addition to ribosomes, certain minute particles composed of RNA and protein have also been found to be present in cytoplasm and nucleus of eukayotic cells. Spirin (1965) called them informsomes. The RNA contained in these is mRNA and hence these are supposed to bear genetic informations. For this reason, these are so named. In the informsomes, the mRNA remains covered by the protein which protects the mRNA from being degraded by the enzyme RNA-ase.

• Different types of ribosomes, their occurrence and subunits :

Туре	Occurrence	Subunits
80 S	Attached to RER of eukaryotic cells	60 S + 40 S
70 S	Freely scattered in the cytoplasm of prokaryotic cells	50 S + 30 S
55 S	Freely scattered in the mitochondrial matrix.	35 S + 25 S

REVISION

Crista-Infolding of mitochondrial inner membrane.

Mitochondrial matrix-A granular, jelly-like material present within the inner chamber of mitochondria.

Mitoplasts-Mitochondria artificially made devoid of the outer membrane.

Chondriosphere-A degenerative structure formed by fusion of mitochondria.

Cytoribosomes-Cytoplasmic ribosomes.

Mitoribosomes—Mitochondrial ribosomes.

Monosome—Freely scatterd ribosomes of prokaryotic cells

Polysome or Polyribosome-Cluster of ribosomes joined together by a mRNA

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RER-Rough endoplasmic reticulum containing ribosomes.

Ribophorins-Proteins which keep ribosomes attached to the RER

Informosomes—mRNA and protein containing cytoplasmic particles which bear genetic information.

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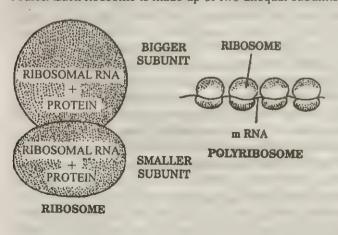


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Sarcoplasmic reticulum-The specialised SER of muscle cells.

2.17. Golgi Body

Definition: Golgi body is a smooth surfaced, membrane enclosed organelle of eukarvotic cells which is concerned with secretion.

Camillo Golgi (1898), an Italian biologist first observed this organelle in the nerve cells, and hence it was named after him. Later, other scientists have called it by various other names such as Golgi complex, lipochondria, dictyosome etc.

Distribution and Number: Golgi body is found in the eukaryotic cells except only a few including mature mammalian RBC. Generally, in secretory cells, a large single Golgi body is found to be located in between the nucleus and cell membrane; examples thyroid cells, panereatic acinar cells, intestinal mucosal cells, *etc.* But in liver cells, nerve cells and various cells of invertebrates and plants, more than one Golgi bodies are present that remain scattered in the cytoplasm.

Origin: The Golgi body remains connected with the ER, and it is believed to originate from ER. Probably at first, small, membrane enclosed vesicles are formed by budding from the SER. These vesicles then join and fuse to form the lamellae or disternae of Golgi body. Some authorities claim that the disternae of RER are transformed into the disternae of Golgi body by detaching their ribosomes. In the cells of some lower plants and animals, the Golgi body may be formed from the nuclear membrane and the cell membrane.

Ultrastructure: The shape of Golgi body changes from time to time. Like the ER, the Golgi body is also made up of membrane enclosed structures of various shapes. These are of three types—

[1] Cisternae or Lamellae: These are membrane bound flatteneed sacs that remain

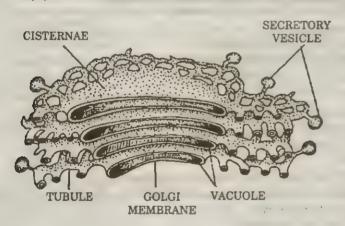


Fig. 2.30: Three dimensional structure of Golgi body. vesicular terminal parts of the cisternae.

stacked one above the other. Two adjacent cisternae are separated by small gap of about 20-30 nm. Each cisterna is a slightly curved structure so that its one surface is concave and the other is convex. The cisternae of Golgi body are devoid of ribosomes and hence are smooth surfaced unlike those of ER.

[2] Vacuoles: These are the swollen and

[3] Tubules and Vesicles: The convex surface of the cisterna remains connected to a network formed by fine, branched tubules. The terminals of these tubules swell to form some minute vesicles. The tubules of Golgi body communicate with the tubules of the ER. For this reason, Golgi body is also claimed to be a part of ER.

The Golgi complex remains surrounded by a zone of cytoplasm where most of the organelles are absent; this is called zone of exclusion.

Chemical composition: Golgi body being an organelle made up of lipoprotein membrane, its chief constituents are lipid (phospholipid) and protein. A few enzymes are also present in it.

Functions of Golgi body:

[1] Secretion: The chief function of Golgi body is secretion from a cell of protein materials e.g. enzymes, hormones etc., that are not easily diffusible through the cell

membrane. After being synthesised in the RER, the secretory proteins pass into the cisternae of Golgi body through the tubules of ER and Golgi body, and are stored in the Golgi vacuoles (at the terminal part of the Golgi cisternae). From here the secretory materials are released in the cytoplasm in the form of membrane bound minute vesicels. These vesicles then pass towards the periphery of the cell and fuse with the cell membrane in such a manner that the secretory materials are expelled out of the cell keeping the cell membrane intact. Thus, the exact role of Golgi body in secretion is to

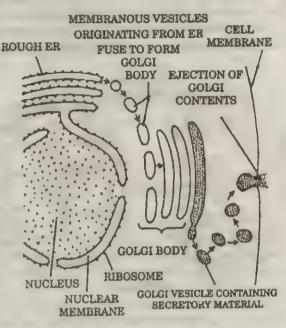


Fig. 2.31: Formation of Golgi body from endoplasmic reticulum (ER) and its role in secretion.

form lipoprotein membrane bound vesicular packets of the secretory material. By the same mechanism the Golgi body also helps in the release of neurotransmitters and neurohormones from nerve cells.

[2] Glycoprotein formation: Golgi body takes part in the synthesis of glycoprotein materials e.g. mucin etc. The protein part of these materials are formed in the RER, and then combined with the sugar derivatives in the Golgi body to produce glycoproteins.

[3] Formation of other organelles: The cell wall and cell membrane contain various glycoprotein materials that are formed in the Golgi body. The Golgi body also helps in the formation of lysosomes.

[4] Sperm maturation: The Golgi body plays an important role in the formation of acrosomal cap of sperms during their maturation.

2.18. Lysosomes [Gr. lysis = dissolution; soma = body]

Definition: Lysosomes are membrane bound vesicular cytoplasmic organelles containing hydrolytic enzymes.

In 1949, Christian de Duve first observed the presence of this organelle in a cell and named it lysosome because of the presence of hydrolytic enzymes in it.

Distribution and Number: Lysosomes are found in almost all animal cells and remain scattered in the cytoplasm. These are not seen in plant cells except those of meristematic tissue. The number of lysosomes in animal cells is variable. These are present in large numbers in secretory cells and WBC.

Origin: Lysosomes are formed by the joint action of ER and Golgi body. The hydrolytic enzymes of lysosomes are synthesised in the RER and then passed to the Golgi body, from where finally by a process of budding, membrane bound and enzyme filled vesicles *i.e.* the lysosomes are released in the cytoplasm.

Ultrastructure: Lysosomes generally look like membrane enclosed vesicles. The surrounding membrane is a trilameller (protein-lipid-protein) single membrane like

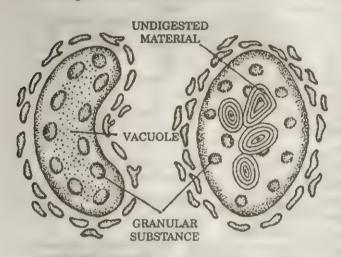


Fig. 2.32: Structure of lysosome.

the cell membrane. The average diameter ranges from 0.2-0.8 um. The shape, size and internal structure of lysosomes are variable. In some cases, the inner part is more dense than its outer part. while in others the outer part is more dense than the inner. Many granules and minute vacuoles are seen within lysosomes. The lysosomes contain numerous hydrolytic enzymes. Lysosomes and

microbodies have similar structures because both are single membrane bound, small, vesicular organelles containing specific enzymes. But they should not be confused because the lysosomes contain hydrolytic enzymes, while the microbodies contain oxidative enzymes.

Functions of lysosome:

- [1] Extracellular digestion: A newly formed lysosome is called primary lysosome, that contains a specific type of enzyme. Some cells secrete lysosomal enzymes into their surroundings for hydrolysis or digestion of extracellular materials. This is called extracellular digestion. Saprophytic fungi derive their nutrition by this type of extracellular digestion. These organisms digest the extracellular organic materials present in their surroundings into small and soluble products that are easily absorbed. In higher animals, the osteoclast cells of bones secrete lysosomal enzymes that hydrolyse the salts deposited in the bone matrix for reorganisation of the bones.
- [2] Intracellular digestion: Digestion of a material within a cell is called intracellular digestion which may be either of the two types—heterophagy and autophagy depending upon whether the material to be digested is exogenous or endogenous respectively.

Heterophagy—This is a process in which a material engulfed by a cell is digested within it. The material (food) engulfed by phagocytosis or pinocytosis forms a digestive

vacuole or phagosome, which then fuses with a primary lysosome to form a secondary lysosome or heterophagosome. Within it, the food particles are hydrolysed and the digestion products are absorbed into the cytoplasm across its membrane. When some undigested residue is left in the heterophagosome. such lysosome is called residual body which expels the excretory materials from the cell by exocytosis.

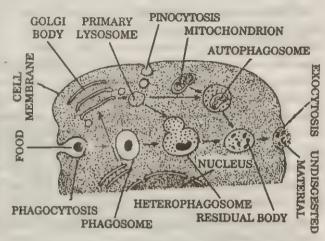


Fig. 2.33: Diagram showing the origin of lysosomes and their role in intracellular digestion.

Autophagy—This is a process by which the old, non-functional and damaged components (organelles) of a cell are digested by its own lysosomal enzymes. In this process, a primary lysosome engulfs a non-functional organelle to form an autophagosome within which the organelle is digested and its constituents are absorbed into the cytoplasm. In case of damage or death of a cell (by heat, mechanical injury, toxicity etc.), the lysosomal membrane undergoes dissolution. As a result, the hydrolytic enzymes are released in the cytoplasm and the entire cell is self digested; this is called autolysis of a cell. This process helps in the regression of defunct tissues of the body; for example—regression of uterus after delivery, atrophy of mammary glands after weaning, disappearance of tail of tadpoles during metamorphosis, etc. The hydrolytic enzymes of lysosomes remain enclosed within its membrane so that the living and active components of a cell are protected from being autolysed. Since rupture of the lysosomal membrane leads to demolition of the cell itself, the lysosomes are quite reasonably designated as the 'suicide bags' of a cell.

- Ambilysosomes: Autophagy and heterophagy may occur simultaneously within the same lysosome. Such lysosomes are called ambilysosomes.
- [3] Bactericidal action: Lysosomes of phagocytic cells (e.g. WBC etc.) contain bactericidal agents that help to kill and destroy the bacteria engulfed by the cell.
- [4] Fertilization: During fertilization, the lysosomal enzyme secreted from the sperms disperse the cells covering the ovum so as to facilitate union of gametes. This is a nice example of extracellular digestion by lysosomal enzymes.
- [5] Hormone secretion: Release of thyroid hormone from its site of storage in the gland (thyroglobulin or colloid) is mediated by the action of lysosomal enzymes of thyroid cells.

- [6] Protection from diseases: Malfunctioning of lysosomes is associated with several diseases like inflammation, arthritis, storage disease, cancer etc.
- Spherosomes or Oleosomes: These are membrane bound spherical or oval bodies rich in lipids, phospholipids and some hydrolytic enzymes like protease, lipase, esterase, phosphatase, ribonuclease etc. This organelle is found in plant cells only. Since these vesicular bodies are bounded by a single membrane and contain several hydrolytic enzymes, they are somewhat similar to lysosomes of animal cells. So, spherosomes are also referred to as lysosomes of plant cells. These are formed by budding from the endoplasmic reticulum. These are found in large numbers in the endosperm cells of the oil bearing seeds. Recently it has been suggested that the spherosomes also contain lipid synthesising enzymes. The primary function of spherosomes is synthesis and storage of lipids. Moreover, they also help in germination of seeds by metabolising the stored lipids with the help of the hydrolytic enzymes present in them.

• What do you mean by endomembrane and endomembrane system (or vacuolar system)?

The intracellular unit membranes of the membranous cell organelles originating from the cell membrane are called **endomembranes**. The interconnected endomembrane bound organelles present within a cell are collectively called **endomembrane system**. It is also called cytoplasmic **vacuolar system** because the endomembranes enclose fluid filled spaces.

The endomembrane system or cytoplasmic vacuolar system 'comprises of (i) the endoplasmic reticulum, (ii) the Golgi complex and (iii) the nuclear envelope. The main function of this system is segregation of proteins within the lumen and their transportation within the cell or export from the cell.

• What is GERL system?

The Golgi complex (G), endoplasmic reticulum (ER) and lysosome (L) are collectively called GERL system because of close functional relationship between them. However, the term GERL is often used to denote a region of SER near the Golgi complex, which is involved in production of lysosomes. The main function of GERL system is secretion of materials from the cells.

• What are the special functions of RER and SER?

The special function of RER (rough endoplasmic reticulum) is protein synthesis because ribosomes are the site of protein synthesis.

The special functions of the SER (smooth endoplasmic reticulum) includes synthesis of lipids, glycogenolysis and detoxication. Moreover, the SER forms the sarcoplasmic reticulum in muscle cells which helps in the conduction of impulse and excitation-contraction coupling.

2.19. Cytoskeleton

Definition: The protein-made, rigid, tubular and filamentous (or fibrillar) structures that form the framework of cytoplasm, give a shape to the cell and help in cellular motions are collectively called cytoskeleton or skeleton of the cell.

The existence of cytoskeleton or an organised fibrous array in the cytoplasm was postulated by Koltzoff in 1928. The cytoskeleton is made up of three kinds of structural elements—microtubules, microfilaments and intermediate filaments.

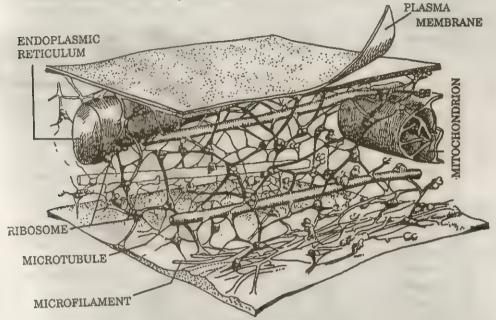


Fig. 2.34: The cytoskeleton.

2.19.1. MICROTUBULES

Definition: Microtubules are protein-made, fine, long, hollow but rigid, unbranched tubular structures present in the cytoplasm of the cells.

De Robertis and Franchi (1953) first observed this cytoplasmic organelle in nerve fibres. Later, in 1963, Slautterback gave its name.

Distribution and Number: Large number of microtubules are found in plant and animal cells. These are singly or freely distributed in the cytoplasm or remain arranged in groups (bundles) in some specialised structures such as centriole, cilia, flagella, nerve fibres, tail of sperms, etc. Microtubules are of two types—permanent (or stable) and temporary (or labile); those present in flagella, cilia, centrioles, sperm-tail etc. are of former (permanent) type, whereas the microtubules scattered in cytoplasm and those found in spindle fibres during cell division are temporary in nature. Microtubules are not found in prokaryotic cells.

Origin: Microtubules are formed by polymerisation of a globular protein called tubulin which is present in the cytosol.

Ultrastructure: These are hollow cylindrical tubes having an outer diameter of approximately 25 nm (250Å). The wall of these tubes is about 5 nm (50Å) in thickness and their hollow core is about 15nm (150Å) in diameter. The length of the tube is variable. The wall of each microtubule is made up of about 13 (10-14) fine, parallel filamentous subunits called **protofilaments** that are arranged longitudinally or spirally around the lumen of the microtubule. The lumen of the microtubules probably remains

filled with cytosol. The protofilaments are composed of a special type of globular protein called tubulin.

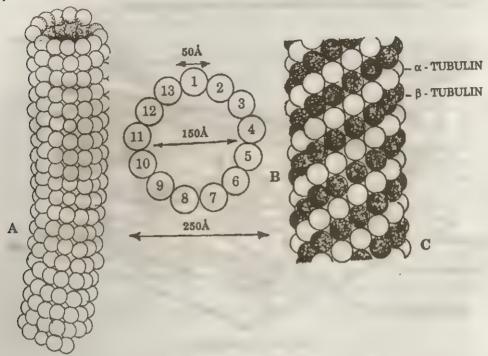


Fig. 2.35: Structure of microtubule:

A-Three dimensional model of microtubule. B-Cross section showing 13 protofilaments making up the wall of microtubule. C-Surface view of a microtubule showing arrangement of units.

Tubulin is a dimer made up of two similar but not identical monomer units called α -tubulin (or tubulin A) and β -tubulin (or tubulin B). In a protofilament, the α -tubulin and β -tubulin units are arranged alternately. A remarkable property of microtubules is their formation and breakdown caused by assembly (or polymerisation) and disassembly (or depolymerisation) of the tubulin unit respectively. This assembly-disassembly process is in a dynamic equilibrium and it is a polarised phenomenon. In a microtubule, the tubulin units assemble at one end and disassemble from the other end. Colchicine is a chemical agent (an alkaloid poison) which prevents polymerisation and assembly of tubulin units and thus the formation of microtubules. So, it is used as a drug to stop mitosis because it impairs the formation of spindle microtubules.

In addition to tubulin, the microtubules also contain several other proteins in small quantities. These proteins take part in assembly of tubulin units and hence they are called *microtubular associated proteins* or MAPs.

Functions of microtubules:

- [1] They form the framework or cytoskeleton of the cell and thereby give mechanical support and a shape to the cell.
 - [2] The microtubules help in the formation of cilia and flagella and their movement.
- [3] They form spindles during cell division and help in the migration of daughter chromosomes towards the poles.

[4] Probably the macromolecules are transported within the cell from one part to another through these tubules.

[5] Microtubules help in morphogenesis or change of shape of the cells during cell

differentiation e.g. formation of sperm from spermatid.

[6] Microtubules present in the sensory cells may play some role in sensory transduction or formation of nerve impulses when the sensory cells are stimulated.

Microtubular organelles :

Several cell organelles are derived from assemblage of microtubules. Major such organelles are centrosomes, cilia and flagella that are described below.

2.19.1.A. CENTROSOME [Gr. kentron = centre, soma = body]:

Definition: Centrosome is a more or less spherical mass of dense cytoplasm situated close to the nucleus and contains a pair of cylindrical bodies that are concerned with spindle formation during cell division.

Boveri (1888) first described this organelle and gave its name.

Distribution: Centrosome is present in most of the animal cells. Although it is found in some lower plant cells such as flagellated alga, it is absent in the cells of higher plants.

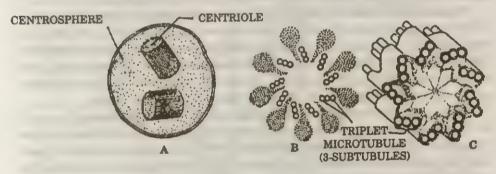


Fig. 2.36: Diagrammatic representation of the structure of centrosome: A-a centrosome, B-T.S. of a centrole, C-three dimensional view of the organisation of microtubules in a centrole.

Ultrastructure: The organising material of centrosome is also known as kinoplasm. It is divisible into two parts—centrioles and centrosphere. At the centre of the centrosome, there are two hollow cylindrical structures called centrioles lying with their long axes more or less perpendicular to each other. The two centrioles of a centrosome are collectively called diplosome. The mass of dense amorphous cytoplasmic material that surrounds the centrioles is termed centrosphere. Each centriole is about 0.5 µm (5000Å) long and 0.2 µm (2000 Å) in diameter. The wall of the centrioles is made up of 9 longitudinally arranged bundles of microtubules. Each bundle is connected with the adjacent one and also with a central rod by means of protein fibres. In cross section, a centriole looks like a cart-wheel. The microtubular bundles are radially equidistant from the central rod and each bundle is equidistant from the adjacent ones. Each bundle is composed of a set of three microtubules and hence called triplet microtubule. These three subtubules or subfibrils are parallel to each other and remain arranged tangentially to the circumference of the centriole. Each subtubule (or microtubule) has an average diameter of about 250Å and its wall is made up of 13

filaments of globular protein (diameter 45Å). Some spheroidal bodies called centriolar satellites encircle the whole centriole in two circumferential rows.

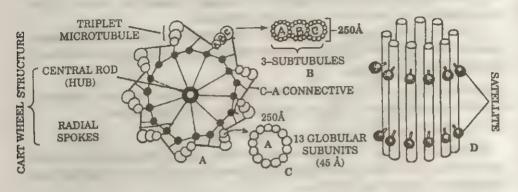


Fig. 2.37: Ultrastructure of centrole (T.S.): A connectives between the triplets and intracentriolar structure; B--structure of a triplet, C-subtubule A; D-a centriole with satellites.

Chemical composition: Chemically centrioles are composed of protein, carbohydrate, lipid and nucleic acids (RNA and possibly DNA also).

Number and Location: When a cell is not undergoing divisions, it contains a single centrosome (a pair of centrioles) which is situated just beside the nucleus at its one end. Prior to cell division (during the interphase stage) each centriole replicates and as a result, two pairs of centroles are produced that lie close together. Later, during cell division, these two pairs of centrioles move to the opposite poles, i.e. one pair goes to one side of the nucleus and the other pair moves to the opposite side.

Origin: Centrioles are believed to originate by replication of the pre-existing ones. It is a very complicated process, the mechanism of which is not fully known. It has been observed that during this, a procentriole is formed just beside each mother centriole and each procentriole remains at right angles to its respective mother centiole. The procentrioles are similar to the mother centrioles but are shorter in length. Later, the microtubules of the procentrioles increase in length and they are converted to mature centrioles. Although the procentrioles lie close to the mother centrioles in a definite arrangement, there is no connection between them and it is yet to be proved unequivocally that a new centriole originates by the division of a pre-existing one.

Functions of centrosome:

The centrosome (centriole) takes part in the formation of various types of microtubules in a cell and thereby it helps in the following two functions:-

[1] Cell division: During cell division, the centrioles form spindle fibres that help in migration of daughter chromosomes towards the poles.

[2] Movement and locomotion of cells: Centrioles help in the formation of cilia, flagella, tail of sperms, etc. which are made up of microtubules and function as organs of movement and locomotion of certain cells.

2.19.1.B. CILIA AND FLAGELLA (Sing. Cilium and Flagellum):

Definition: Cilia and flagella are hair-like microtubular organelles projecting from the cell surface into the extracellular medium and are concerned with cell motility. Cilia and flagella are fundamentally similar but they vary in size, length and number.

They are called cilia if they are short and numerous (hair-like) but if they are few (one or two in number) and long (whip-like) they are called flagella.

Occurrence: Although cilia and flagella are found only in certain cells (i.e. not in all eukaryotic cells), they occur in both plant and animal cells. However, their occurrence in plants is relatively less than that in animals.

In plants, the cilia are rare and flagella are found in the gametes of algae, aquatic

fungi, bryophytes, pteridophytes and gymnosperms.

In animals, cilia and/or flagella are found in all the groups. However, cilia are more commonly seen than flagella in animal cells. Cilia are present on the surface of all the members of an entire class of Protozoa, the Ciliata (e.g. Paramoecium, Vorticella), larvae of Echinodermata, Mollusca and Annelida, ciliated epithelial cells lining the trachea, oviduct and fallopian tube of diffrent vertebrates, etc. On the other hand, flagella are found in all the members of an entire class of Protozoa, the Flagellata (e.g. Euglena, Trychonympha etc.), collar cells of sponges, gastrodermal cells of Coelenterata, spermatozoa of higher

animals, etc.

Origin: Cilia and flaglla originate from the basal bodies which in turn originate from centrioles.

Ultrastructure: The ciliary apparatus (i.e. a cilium or a flagellum) consists of two main parts-the shaft and the basal body. Two other structures called ciliary rootlets and mastigonemes are also found in the ciliary apparatus of some cells.

[1] Shaft-The shaft is the cilium proper or the filamentous part projecting out from the cell surface. The shaft consists of a basic microtubular framework called axoneme or axial complex which is embedded in the ciliary ground substance and "is matrix surrounded by the ciliary membrane which is continuous with the

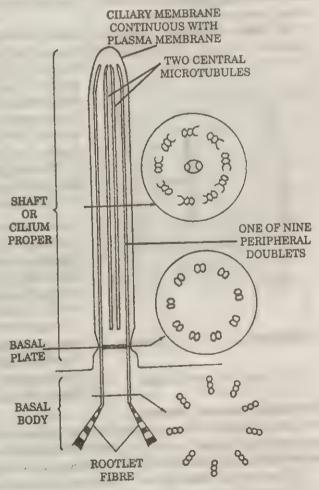


Fig. 2.38: Structure of a cilium.

plasma membrane. Each axoneme contains a bundle of microtubules, which run longitudinally along its length. These microtubules are arranged in such a way that there are two in the centre surrounded by a ring of nine paired ones, called doublets. This arrangement is described as 9+2 pattern (i.e. 9 pairs of peripheral microtubules and 2 single, central microtubules). The peripheral doublets have two arm-like processes made up of a protein called dynein which works as ATP-ase for release of energy during the movement of cilia or flagella. The two central microtubules lie side by side within a central sheath. The peripheral doublet microtubules are connected to the adjacent ones and also with the central microtubules.

[2] Basal body—The part of the cilium or flagllum lying below the level of the cell membrane from which the cilium or flagellum originates is called basal body or basal granule or blepharoplast or kinetosome. The basal body is composed of a ring of 9 peripheral microtubules continuous with those in the shaft. However, the two central microtubules are absent and the peripheral ones are in threes (triplets). Thus, the basal body structurally resembles the centriole. The basal body and the shaft is separated by a basal plate (or ciliary plate).

[3] Ciliary rootlets—In some cells, specialised striated structures called ciliary rootlets may be seen, which originate from the basal body and penetrate into the deeper

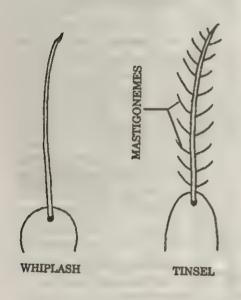


Fig. 2.39: Types of flagella.

layers of the cytoplasm. These rootlets probably serve as anchors for the basal body. They are commonly found in the ciliated epithelium of lower animals but are absent in the ciliated epithelium of mammals and the ciliated protozoa.

[4] Mastigonemes—These are small hair like lateral appendages present on the shaft of some flagella

Types of cilia and flagella:

Cilia are distinguished into two typeskinocilia and stereocilia. The kinocilia are motile and have the microtubular structure, whereas the stereocilia are non-motile and lack the microtubular structure.

Flagella are also of two types-tinsel type and whiplash type. The tinsel type flagella possess lateral hair like appendages (mastigonemes), whereas whiplash type of flagella are devoid of them.

Functions of cilia and flagella:

Cilia and flagella are contractile processes of the cell. Flagella are nearly always associated with locomotion, but cilia perform other functions as well by creating currents in the medium. The function of cilia and flagella are as follows—

- [1] Locomotion-Both cilia and flagella help in locomotion of various invertebrates.
- [2] Feeding—In many aquatic animals, the ciliary currents carry the food particles present in the external fluid medium towards their digestive system for feeding.

[3] Respiration and circulation-In animals lacking a true blood vascular system, the coelomic fluid is kept circulating by the ciliary movements. This also helps in exchange of gases.

[4] Transport of materials-The rapid and rhythmical beatings of the cilia help in transport of materials within the ducts and tubules of the body that are lined by ciliated epithelium. Transport of ovum in the fallopian tube is a good example of this function.

[5] Cleansing-The beating of cilia helps in cleansing by sweeping away the undesirable particles or by trapping them. For example, the cilia of the epithelium lining the respiratory passage of vertebrates trap dust particles and prevent their entry into the lungs.

[6] Sensory function-Bending of cilia of the auditory and vestibular receptors by the pressure of the fluid bathing them elicits respective sensations. This is a good example of sensory transduction by cilia or microtubules.

● Difference between Cilia and Flagella ●

 They are found in large numbers (over 3000). They usually occur all over the cell surface. They are short (5-10μm in length). They are much longer (upto 200 μm in length). They beat in a co-ordinated way with sweeping. They are concerned with locomotion and many other functions e.g. feeding, circulation, respiration, cleansing, transport and sensation. 	Difference perween cum and tage				
 They usually occur all over the cell surface. They are short (5-10μm in length). They beat in a co-ordinated way with sweeping. They are concerned with locomotion and many other functions e.g. feeding, circulation, respiration, cleansing, 	Cilia	Flagella			
transport and sonsation.	 3000). They usually occur all over the cell surface. They are short (5-10μm in length). They beat in a co-ordinated way with sweeping. They are concerned with locomotion and many other functions e.g. feeding, 	 l or 2). They usually occur at one end of the cell. They are much longer (upto 200 μm in length). They beat independently in undulatory motion. They are concernd with 			

Difference between flagella of bacteria and flagella of eukaryotic cells.

The bacterial flagella are 100-300Å in width and are made up of a protein called flagellin, whereas the flagella of eukaryotic cells are wider, about 1000-3000Å in diameter, and are made up of a protein called tubulin.

2.19.2. MICROFILAMENTS

Definition: Microfilaments are protein made fine filamentous cytoskeletal structures that are not tubular but solid.

Occurrence: Microfilaments are present in eukaryotic cells only, and not in prokaryotic cells. They occur in both plant and animal cells mainly beneath the cell membrane. They also occur in bundles in the deeper parts of cytoplasm where they are associated with cell motility e.g. in the myofibrils of muscles cells, the plant cells showing cytoplasmic streaming (cyclosis) etc.

Origin: Microfilaments are formed by polymerisation of some globular proteins present in the cytosol.

Ultrastructure and Chemical composition: Microfilaments are 5-7nm (50-70Å) in width, i.e. their diameter is about a quarter the diameter of the microtubules. The microfilaments are made up of a protein called actin. The actin filament (or F-actin) is a polymer of thousands of globular actin monomer (or G-actin) molecules and it is a

double helical structrue i.e. two chains formed by G-actin molecules remain twisted around each other. Some other proteins like myosin, tropomyosin, tropomyosin, tropomin and α -actinin may also remain attached to the actin microfilaments. Thus, the proteins of the microfilaments are similar to the muscle proteins. Like the microtubules, the microfilaments can also be readily assembled (polymerised) or disassembled (depolymerised) and this plays an important role in cell movement.

Functions of microfilaments:

- [1] Microfilaments contribute to the formation of cytoskeleton of the cell and gives mechanical support to the cell.
- [2] The chief function of microfilaments is to help in cell motility of various kinds as described below:-
- (i) Cytoplasmic streaming (or Cyclosis)—It is observed in mature plant cells in which the cytoplasm is reduced to a perpheral layer around a large central vacuole. In such cells, continuous current is seen in the cytoplasm which is called cyclosis or cytoplasmic streaming. This is caused by the microfilaments present in the cytoplasm.
- (ii) Amoeboid movements—This is observed in certain protozoa

 Fig. 2.40:

 Structure of microfilament.

 in locomotion of the cells. The movement of pseudopodia which help in locomotion of the cells. The movement of pseudopodia is also caused by microfilaments present beneath the cell membrane.
- (iii) Muscle movements—The contraction of muscle cells is carried out by the microfilaments of the muscles (myofilaments).
- (iv) Other types of cell motility—Microfilaments present beneath the cell membrane help in many other cell-functions involving movement or bending of the cell membrane. These are cytokinesis, endocytosis, movement of microvilli, cell spreading, shape change etc.

2.19.3. INTERMEDIATE FILAMENTS

In addition to the microtubules and microfilaments, the cytoskeleton of many cells contain some filaments having a mean thickness of 10 nm (100Å). These are called *intermediate filaments* because their diameter is in between the microtubules and microfilaments.

The intermediate filaments can be grouped into four main types: -

- [1] Keratin filaments—These are made up of the protein called keratin and are also called tonofilaments or prekeratin filaments or cytokeratin filaments. These are found in epidermal cells of skin and desmosomes of epithelial cells.
- [2] Neurofilaments—These filaments are present in axons, dendrites and perikarya of neurons.

- [3] Glial filaments—These filaments are present in the astrocyte type of glial cells (but not in the oligodendrocytes) of brain.
- [4] Heterogenous filaments-This group is so named because they contain a variety of proteins such as *desmin*, *vimentin* and *synemin*. Such filaments are found in muscle cells (where they hold the myofibrils) and in many other cells (where they form perinuclear caps).

The intermdiate filaments are involved in mechanical functions that determine the cell shape and position of various compartments within the cell.

REVISION

Autophagy Digestion of cellular components by the cells's own lysosomal enzymes. Primary lysosome—A newly formed lysosome that has not yet fused with other vesicles.

Secondary lysosome or Heterophagosome—A lysosomal vesicle formed by fusion of a primary lysosome with a digestive vacuole.

Heterophagy—Digestion of food engulfed by phagocytosis or pinocytosis within the cell with the help of lysosomal enzymes.

Autolysis of a cell-Self digestion of an entire cell by the lysosomal enzymes due to rupture of lysosomes.

Cytoskeleton—The complex cytoplasmic network or framework of cytoplasm formed by microtubules, microfilaments and intermediate filaments.

Kinetochore-Region of the centromere to which the spindle microtubules attach during cell division.

Kinetosome or Basal body or Blepharoplast—The microtubular structure similar to centriole that serves as the attachment site for cilia and flagella.

Kinoplasm-The organising material of centrosome.

Centriole—The hollow cylindrical microtubular organelle involved in organisation of the spindle.

Centrosphere—The mass of cytoplasmic material within the centrosome surrounding the centrioles.

Diplosome-Collection of the two centrioles in a centrosome.

2.20. Plastids

Definition: Plastids are double-membrane bound, pigmented or nonpigmented cytoplasmic organelles found in plant cells and concerned with manufacture or storage of food or colouration.

Schimper (1883), first introduced the name 'plastid' for these specialised plant cell organelles. Plastids are present in all eukaryotic plant cells except fungi. Hence the presence of plastids is considered as a characteristic feature of plant cells. Animal cells are devoid of this organelle. A few unicellular animals (protozoa) e.g. Euglena, Chris amoeba, etc. are exceptional and they possess plastid (chloroplast). For this reason, the botanists claim these organisms as plants. Although the prokaryotic cells do not contain well organised plastids, the cells of autotrophic bacteria and blue green algae possess some membrane-bound, pigment-containing structures e.g. chromatophores or lamellae which are considered as substitutes of plastids.

Typs of plastids: Depending on their colour and function, plastids are of three types-chloroplast, chromoplast and leucoplast. Among these, the chloroplast is most important and it has been extensively studied.

I. Chloroplast: Chloroplasts are green coloured plastids concerned with

photosynthesis.

Distribution and Number: In plant cells, chloroplast is the most widely distributed

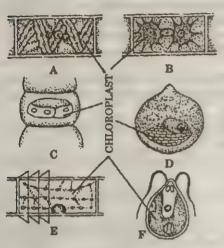


Fig. 2.41: Chloroplasts of various shapes found in algae. A-ribbon like (Spirogyra), B-stellate F-cup shaped (Chlamydomonas).

plastid. It is found in all green parts of a plant (rather the parts of a plant containing this type of plastid look green). Chloroplasts are present in largest number in the mesophyll cells of leaves. The number of chloroplast varies from one type of plant cell to another, but it is generally fixed for a particular type of cell (different cells of the same type of tissue of plants belonging to the same species). Cells of algae contain a single chloroplast that occupies a definite position within the cell and remain organised in a characteristic manner. In higher plant-cells, e.g. mesophyll cells of leaves, the number of chloroplast may be upto 20-40. In these cells, the plastids remain scattered in the cytoplasm or in close shaped (Anthoserus), E reticulatee (Oedogonium), contact with the cell membrane or nuclear membrane.

Origin: In lower plant cells, the chloroplasts divide during cell division and become equally distributed in the daughter cells. On the other hand, in higher plants, all plastids are thought to originate from specialised membrane bound, vesicular, colourless structures called proplastids present in the

meristematic tissue cells. In presence of sunlight, these proplastids are transformed into chloroplasts.

Ultrastructure: The shape and size of chloroplast varies from species to species. It is like a spiral ribbon in Spirogyra, reticular in Oedogonium, ring-like in Ulothrix, cup shaped in chlamydomonas, stellate in zygnema, disc-or lens-like in higher plant cells, etc. Chloroplasts of higher plant cells are 4-6 µm in diameter and about 1 µm in thickness.

Like the mitochondria, chloroplasts are also bounded by two concentric limiting membranes, each of which is a trilameller (protein-lipid-protein) unit membrane. The contents of chloroplast present inside the

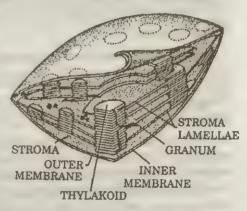


Fig. 2.42: Structure of chloroplast (3 dimensional).

inner membrane are divisible into two parts-stroma and grana (sing. granum). The stroma is a homogenous, protein-rich, fluid matrix or ground substance of the chloroplast

that bathes the grana. It contains photosynthetic enzymes. The grana are membranous structures that remain embedded within the stroma. Each chloroplast contains about 40-60 grana. A granum is made up of several (upto 50) small, flat, disc-like, membranous sacs called thylakoids that remain stacked one above another. Each thylakoid is formed by unit membrane. Adjacent grana are interconnected by a membranous tubular network called intergranal lamellae or stroma lamellae. The inner surface of thylakoid membrane contains numerous minute, roughly spherical bodies called quantosomes

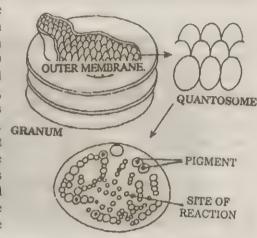


Fig. 2.43: Ultrastructure of grana.

that are filled with pigments, mainly chlorophyll (green) and small amounts of carotene (orange) and xanthophyll (yellow).

Chemical composition: The chief chemical constituents of chloroplasts are proteins, lipids and pigments. The membranous parts of the chloroplasts are made up of proteins and lipids (P-L-P). The stroma is composed of proteins (enzymes) mainly. The quantosomes present within the thylakoids contain two types of pigments -chlorophylls (chlorophyll-a and chlorophyll-b) and carotenoids (carotene and xanthophyll). In addition to the above materials, small amounts of DNA, RNA, ribosome particles, starch and some minerals have also been found to be present in the chloroplast of higher plants.

Functions of chloroplast:

- [1] The function of chloroplast is **photosynthesis** in which the chlorophyll present in it captures the solar light energy and converts it into chemical energy that is used for synthesis of glucose from CO₂ and water. By this process, solar energy is stored as chemical energy. As the chloroplasts help in the transformation of energy from one form to another, these are also considered as the transducer of plants.
- [2] The enzymes present in chloroplast may also synthesize RNA, proteins and fatty acids.
- II. Chromoplast: Plastids having colours other than green are called chromoplasts. These are spherical or star shaped or elongated rod-like structures. Chromoplasts also contain membranous lamellae which are not stacked like the thylakoids of chloroplasts. They contain negligible amount of chlorophyll and hence are incapable of photosynthesis. The pigments present in chromoplasts are mainly carotenoids such as carotene (orange), xanthophyll (yellow), lyocopene (red), etc. In addition to these, phycoerythrin (red) and phycocyanine (blue) pigments are also found in chromoplasts.

Chromoplasts having different colours are found in various parts of the plants e.g. flower, fruit, root, etc. The chief function of chromoplasts is to provide colour to

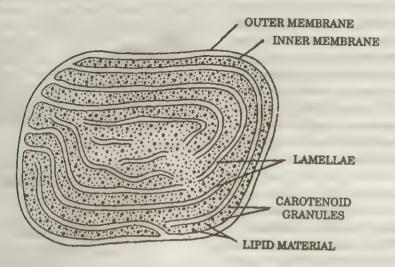


Fig. 2.44: Structure of chromoplast.

various parts of the plant, which attracts insects and other animals for pollination and dispersal of seeds.

III. Leucoplast: Colourless plastids (which are devoid of pigments) are called leucoplasts. These are rod-like or spherical or oval in shape. They possess membranous

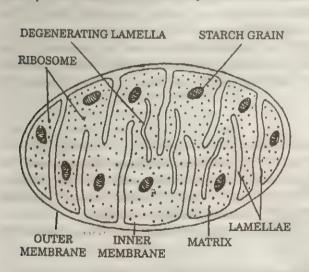


Fig. 2.45: Structure of leucoplast.

lamellae that do not form thylakoids. Leucoplasts are found in gametes, embryonic cells and the cells of those parts of the plant which are not exposed to sunlight. The function of leucoplasts is to convert soluble simple food matters into insoluble complex materials for their storage. For this reason, leucoplasts are abundant in storage organs of plants such as fruits, seeds, underground roots and stems etc. (these parts are not exposed to sunlight). According to the

stored food in them, the leucoplasts may be of the following three types: (i) Amyloplast—It stores starch, and is found in underground stems (e.g. potato), cereals (e.g. rice, wheat) etc. (ii) Proteinoplast or Aleuronoplast—It stores proteins, and is found in seeds. (iii) Elaioplast—It stores oils, and is found in the seeds of mustard, nuts, coconut etc.

In this context, it should be mentioned that one type of plastid may be transformed into another type. For example—(i) during ripening of fruits, the chloroplasts present in

their skin (peel) are transformed into chromoplasts so that the colour of the fruit changes from green to yellow or red; (ii) chloroplasts are transformed into leucoplasts, if they are deprived of sunlight for a long time; on exposure to sunlight, these leucoplasts are reconverted into chloroplasts.

• Why mitochondria and chloroplasts are called semi-autonomous organelles?

Both mitochondria and chloroplasts are self sufficient or autonomous in many respects such as (i) they have their own energy generating (ATP forming) system, (ii) they possess DNA, RNA and ribosomes for protein synthesis and (iii) they originate from pre-existing organelles. However, the biogenesis of these two organelles is highly dependent on the nucleus and the rest of the cytoplasm. Thus, mitochondria and chloroplasts are partly autonomous and partly dependent on the rest of the cell; hence they are called semi-autonomous organelles.

• What are the similarities between mitochondria and chloroplasts?

Although mitochondria and chloroplasts are functionally of opposite nature (because they are concerned with catabolism and anabolism of food respectively), they are similar in many respects as follows:—

- (i) Both are double membrane bound organelles.
- (ii) They contain oxido-reductase enzyme systems.
- (iii) Both of these organelles have ATP-generating system.
- (iv) Both contain DNA, RNA and ribosomes and are capable of protein synthesis.
- (v) Both of these can originate from pre-existing organelles and are of semiautonomous nature.

2.21. Vacuoles [Vacuous = vacant or empty]

Definition: Vacuoles are membrane bound, apparently empty spaces or cavities within the cytoplasm.

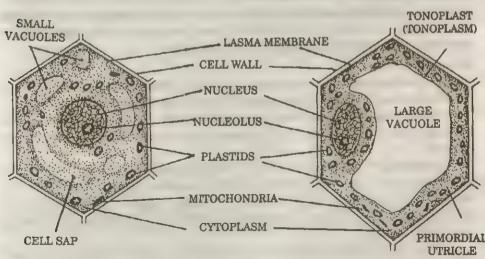


Fig. 2.46: Diagrammatic representation of vacuoles in plant cells. A-young cell, B-mature cell **Distribution and Number:** Generally the cells of higher animals do not possess

vacuole. Unicellular animals may possess vacuoles which are only a few in number and small in size. Plant cells contain much larger vacuoles. In immature plant cells, there are many vacuoles but in mature plant cells, the vacuoles coalesce to form a single large vacuole. This is possibly because the volume of cytoplasm does not increase proportionately with the cell size. This large vacuole (of a mature plant cell) occupies most of the cell centrally, pushing the cytoplasm and nucleus towards the periphery in the form of a thin film just beneath the cell membrane. Such a thin cytoplasmic layer is called **primordial utricle.**

Origin: Vacuoles originate from cell membrane or Golgi body or endoplasmic reticulum.

Structure: Although the vacuoles appear to be cytoplasm free empty spaces, these are actually filled with a watery fluid or gaseous or oily material. The fluid present in the vacuole is called **cell sap** in which sugar, salts and various excretory materials (produced as a result of metabolism in the cell) or secretory materials remain in dissolved or crystalline or amorphous form. Such a vacuole containing cell sap is called **sap vacuole**. In some cases, the vacuoles may contain pigments or food stuff (engulfed by phagocytosis). The vacuoles of some algae contain oils or gases.

• What are tonoplast and protoplast?

These two terms are related to plant cells. An interesting feature of a typical plant cell is that the centre of the cell is occupied by a large vacuole, filled with a solution containing sugar and salts. This vacuolar solution is called cell sap which remains separated from the rest of the protoplasm by means of a membrane so that the protoplasm of the cell is restricted peripherally around the vacuole. Thus, as a consequence of the presence of vacuole, there are two membranes in these cells, one lining the outer surface of the cytoplasm (just inside the cell wall) and the other lining the inner surface of the cytoplasm bordering the vacuole. The former (or the membrane covering the outer surface of cytoplasm is called plasma membrane, whereas the latter (or the membrane separating the cytoplasm and the vacuolar cell sap) is called **tonoplast** or **tonoplasm**. The protoplasmic material present inside the plasma membrane (i.e. in between plasma membrane and tonoplast) is referred to as the **protoplast**.

Functions of vacuoles:

Vacuoles function as the storage organs of a cell. Depending upon their contents the vacuoles may be of three types, each having a definite function as follows:-

- [1] Food vacuoles—These contain food materials taken into the cell by the process of phagocytosis or pinocytosis. The function of food vacuoles is to store the food and digest it.
- [2] Excretory vacuoles—Vacuoles containing exretory materials are found in protozoa and plant cells. These vacuoles help to protect the cytoplasm of a cell from the toxic effects of the excretory materials. In protozoa, these vacuoles contract and relax alternately to expel the waste matters from the cell; such vacuoles are called contractile vacuoles.
- [3] Gas vacuoles—Gas filled vacuoles found in the cells of some aquatic plants (e.g. algae) help them to float.

In addition to the above functions, the vacuoles also help to regulate the turgor pressure of the cells.

REVISION

Plastid—Double membrane bound organelle of plant cells, concerned with synthesis or storage of food or colouration.

Chloroplast—Chlorophyll (green pigment) containing plastid in which photosynthesis occurs.

Leucoplast-Colourless plastid in which food in stored.

Chromoplast-Plastid containing non-green pigments, that are responsible for colouration of plant organs.

Amyloplast-Leucoplast in which starch is stored.

Proteinoplast or Aleurone plast-Leucoplast in which protein is stored.

Elaioplast-Leucoplast in which oil is stored.

Phaeoplast—Chromoplast containing the brown pigment fucoxanthine, found in diatoms and brown algae.

Rhodoplast-Chromoplast containing the red pigment phycoerythrin.

Periplastidial space-Space between the two membranes covering the plastids.

Thylakoid—Chlorophyll containing flattened vesicle found in chloroplasts, in which the light dependant reactions of photosynthesis take place.

Granum—A Stack of thylakoids containing chlorophyll, that remians embedded within the storma of chloroplasts.

Quantosome-Spherical bodies present within the thylakoid, that contain the photosynthetic pigments.

Plastidome-Collection of genetic informations carried by the plastid system.

Tonoplast or Tonoplasm—The membrane covering the large central vacuole or cell sap of the mature plant cells.

Protoplast-The protoplasmic material in between the plasma membrane and tonoplast of a plant cell.

2.22. Cytoplasmic Inculsions or Ergastic Substances [ergastic = having potential energy]

Definition: The non living matters scattered in the cytoplasm are called cytoplasmic

inclusions or ergastic substances or deutoplasm.

Unlike the cytoplasmic organelles, the cytoplasmic inclusions are neither the metabolic machinery nor the site of metabolism in a cell; rather these are products of metabolism. Functionally these are of **four** types-[1] stored food, [2] secretory matters, [3] excretory matter and [4] pigments.

[1] Stored food: Living cells do not store large quantities of food material in simple (low molecular weight) and soluble forms (e.g. glucose) because this would lead to a state of osmotic imbalance. For this reason, the excess simple food matters manufactured by the cell or procured by it from outside are converted to large molecules (e.g. glycogen, starch etc.) that are stored in the cell as reserve food for future use. These complex molecules do not create osmotic imbalance. The reserve food of cells are mainly of three types—(i) carbohydrates, (ii) fats and oils and (iii) proteins.

(i) Carbohydrates: These are the chief reserve food of the cells. Among these, the most important ones are starch and glycogen; however some cells may store other cerbahydrates.

carbohydrates.

(a) Starch—It is a polysaccharide made up of glucose and is found only in plant cells. Animal cells do not contain starch. In plant cells, glucose molecules manufactured by photosynthesis are polymerised to form starch, which remains scattered in the

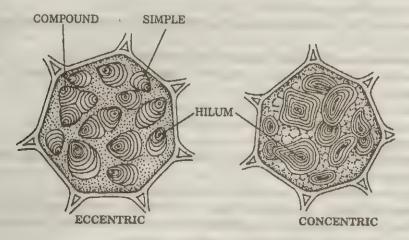


Fig. 2.47: Starch grains.

cytoplasm as granules called starch grains. Almost all plant cells possess starch grains and an abundance of it is seen in storage organs like seeds, cereals, underground stems, roots etc. The starch grains may be of different shapes such as oval (potato), flat and round (wheat), spherical (pea), polygonal (maize) etc. In each starch grain, successive layers of starch are deposited around a dark refractile portion called hilum. The hilum may be placed centrally or at one end near the periphery and accordingly such starch grains are called concentric or eccentric respectively. The starch grains may be simple (each grain separated) or compound (more than one grains joined together).

(b) Glycogen-This is also a polysaccharide of glucose. It is found in animal cells, mainly in the cells of liver and muscle. It is absent in plant cells except some fungi.

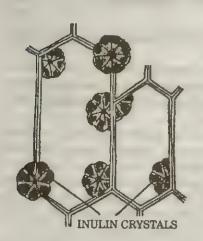


Fig. 2.48: Inulin crystals in the cells of Dahlia tuber (root).

Hence, it is also called animal starch. In vertebrates, liver and muscle cells store large quantities of glycogen in the cytoplasm as very fine insoluble particles.

- (c) Other carbohydrates-Inulin, a polysaccharide made up of fructose is stored in the cells of tuberous roots of Dahlia and some plants of this family. It is a soluble carbohydrate, but it forms beautiful fan shaped crystals when the tuber of Dahlia is kept in alcohol for a few days. Sugars are stored in certain plant cells in dissolved state; for example glucose and fructose in various fruits, sucrose in sugarcane etc.
- (ii) Fats and oils: These are compounds (esters) of fatty acid and glycerol. Compounds of this type that remain solidified under

ordinary room temperature are called fats, whereas those remaining in liquid state are

called oils. Plant cells generally store oils whereas the animal cells store fats. These can also be synthesised from carbohydrates within the cell

Fats and oils are stored as fine droplets in the cytoplasm. In plants, abundance of oil storage is seen in the seeds (mustard, nuts, castor etc.) and crops (coconut). In animals, adipose tissue and liver cells are the chief sites for fat storage. In adipose tissue cells, the cytoplasm is generally so heavily loaded with fat droplets that the nucleus is pushed peripherally.

(iii) Proteins: Proteins are composed of amino acids. Generally, these are not stored as cytoplasmic inclusions. Majority of the proteins present in cytoplasm are enzymes, that remain in the matrix in colloidal state or in the organilles. In animal cells, proteins mainly form the cytoskeleton and are not stored as reserve food. In some

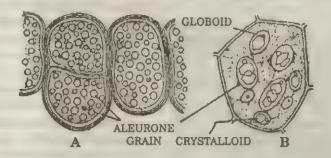


Fig. 2.49: Aleurone grains in plants cells: A in maize, B in castor seed

plant cells, protein granules called **proteid grains** remain scattered in the cytoplasm as ergastic material. In the storage organ of plants such as seeds, these are called **aleurone grains**. Seeds containing less starch have bigger aleurone grains *e.g.* castor seed; whereas those having large quantities of stored starch (*e.g.* maize seed) contain aleurone grains of smaller size. The aleurone grains of castor seed are oval or spherical having two parts -a larger polyhedral part called **crystalloid** and a smaller spherical part called **globoid**. Aleurone grains are also present in the seeds of gram, pea, soyabean *etc.* and some cereals *e.g.* wheat.

[2] Secretory matters: In animal cells, the secretory materials stored as cytoplasmic inclusions may be of three types-zymogens, hormones and neurotransmitters. Zymogens are inactive precursors of enzymes stored in the cells of digestive glands. These are activated after being secreted from the cell. This is why the cells of the digestive glands are not self-digested. Examples of zymogens are pepsinogen (precursor of pepsin) in peptic cells of stomach, trypsinogen in acinus cells of pancreas etc. Hormones of some endocrine cells and neurotransmitters of nerve cells are also stored as cytoplasmic inclusions.

The chief secretory inclusion of plant cells is **necter** composed of sugar. It is found in the cells of flowers and attracts the insects for pollination.

[3] Excretory matters: As a result of metabolism, various unnecessary and toxic substances (waste products) are produced within the cells. In animals, the waste products are generally soluble in water and expelled from the cell to the extracellular fluid from where these are excreted out of the body through the excretory organs. For this reason, the excretory matters are not stored in the animal cells to a considerable extent. On the

other hand, plants do not have specialised excretory organs and their waste products are generally insoluble in water. Hence, these materials are stored as cytoplasmic inclusions within various organs of plants and are cast off with those organs. Most of the waste products of plants are useful to mankind. The excretory matters of plants stored as cell inclusions are the following:—

- (i) Tannins—These are found as granular masses with yellow or brown or red colour in the leaves and barks of plants like tea, hemlock, pine, datepalm, betelnut palm, etc.
- (ii) Gums-These are amorphous colloidal compounds found in the stems of plants. Some common examples of plant gums are camphor, dhuna, goggul, gum arabic, gum acacia, cherry gum etc. Gums may be collected within gum ducts or some xylem vessels.
- (iii) Mineral crystals—In plant cells, mainly two types of calcium salts are deposited as crystalline inclusions; these are crystals of calcium carbonate and calcium oxalate.

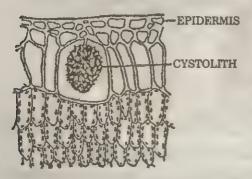


Fig. 2.50: Cystolith in India-rubber leaf.

Calcium carbonate crystals called cystoliths look like bunch of grapes and are found in the leaves of banyan, fig, rubber etc. The specialised and enlarged cells containing cystoliths are termed lithocysts. Calcium oxalate may be deposited as solitary rod like or prismatic or polyhedral crystals as found in the cells of onion scale leaves. The calcium oxalate crystals may also be aggregated to form specialised compound structures called raphides,

that occur in the cells of leaves and stems of water hyacinth, water lettuce, *Colocasia* (taro), yam *etc.* The specialised cells in which these crystals are stored are called **idioblasts.** Raphides may be either star-shaped called **sphaeraphide**, or like a bundle of fine needle-shaped crystals called **acicular raphide**.

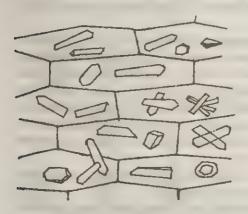


Fig. 2.51: Various forms of calcium oxalate crystals in dry scale leaf of onion.

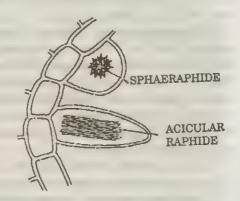


Fig. 2.52: Raphides in taro.

(iv) Volatile oils—Volatile oils (also known as essential oils) are widely found in plants. These may occur in various parts of the plants e.g. stems, leaves, flowers, fruits etc. that possess the so called oil glands. Each of these oils have a characteristic odour.

They differ from common oils chemically (these are not true oils or esters of fatty acids), physically (these evaporate more readily) as well as physiologically (these are waste products rather than being food reserves). Common examples of their occurrence are leaves and fruit skin of lemon; stem and leaves of tulsi, eucalyptus etc.; flowers (petals) of rose, jasmine etc. and fruits of nutmeg, mango etc. Due to the presence of volatile oils, the plant organs containing them are characteristically odorous.

- (v) Resins—These are water insoluble compounds often found in association with gums, essential oils etc. They generally occur within special ducts (called resin ducts) of conifers (e.g. pine).
 - (vi) Latex-This is a white, milky, viscous, colloidal fluid found in specialised cells

or ducts called laticifers present in stems and leaves of banyan, jackfruit, oleander, papaya etc. Laticifers may be simple or compound. Simple laticifers are single cells called latex cells. Compound laticifers are also called latex vessels that are branched structures formed by fusion of series of cells.

(vii) Alkaloids—These nitrogenous compounds having a bitter taste are found in various parts of plants. Alkaloids are insolube in water but soluble in

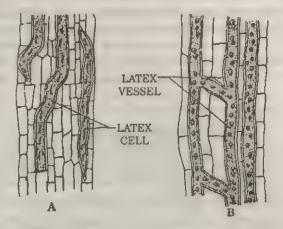


Fig. 2.53: Latex cells (A) and lateex vessels (B).

alcohol. Examples of some common alkaloids are nicotine in the tobacco leaves, strychnine in the seeds of nux-vomica, caffeine in coffee and leaves of tea, quinine in the bark of *Cinchona*, reserpine in the roots of *Rauwolfia seprentina*, morphine in the fruits of poppy etc.

- (viii) Organic acids—Some organic acids are collected in the vacuoles (cell sap) of certain plant cells, particularly those of fruits which taste sour. Common examples are tartaric acid in tamarind, citric acid in lemons, malic acid in apple and tomato, oxalic acid in Oxalis, etc.
- [4] Pigments—Various cells may produce or accumulate certain pigments that make the cells coloured. The chief pigments stored in the plant cells are chlorophylls and carotenoids which are present in the plastids.

The pigments found in animal cells are haemoglobin and its derivatives and melanin. Haemoglobin is a red coloured chromoprotein containing iron and is found in RBC due to which the blood is red. The hemoglobin of old and disintegrating RBCs is broken down into haemosiderine (iron containing pigment) or biliverdin and bilirubin (iron less pigment). Generally, these pigments are not stored in the cells in a considerable amount. But in pathologic states of excessive breakdown of RBC, these are stored in liver and other tissue cells. Melanin is a dark coloured pigment found in the cells of skin, hair, eye etc.

• What are the polysaccharides stored in the cells as reserve food ergastic substance? In which cells they are stored?

The polysaccharides stored as reserve food ergastic substances in the cells are **starch**, **glycogen** and **inulin**. Among these, starch and glycogen are glucans *i.e.* polysaccharides made up of glucose units only, whereas inulin is a fructan *i.e.* a polysaccharide made up of fructose units only.

Starch is stored in plant cells only. Glycogen is stored in animal cells mainly. Inulin

is stored in the cells of the root of Dahlia plant.

• Why starch and glycogen are more suitable than glucose as storage materials for cells?

Glucose cannot be stored in the cells as reserve food in considerable amounts because it is a small and water soluble molecule that would cause osmotic imbalance in the cell. Accumulation of excess glucose in a cell would cause rise in osmotic pressure of the cell cytoplasm, as a result of which the cell would swell up and may even burst due to endosmosis (i.e. entry of water into the cell from outside).

Starch and glycogen are more suitable than glucose as storage materials because unlike glucose, they are large and water insoluble molecules that do not create osmotic

imbalance in the cells.

• What are metaplastic bodies?

Certain non living materials produced by the metabolic activities are stored in animal cells. These materials are collectively called metaplastic bodies. Thus, metaplastic bodies are the *ergastic substances* or *cytoplasmic inclusions* of animal cells. They include glycogen granules, fat globules, zymogens, pigments *etc*.

REVISION

Ergastic substances or Deutoplasm or Cytoplasmic inclusions—Non-living insoluble matters scatterd in the cytoplasm.

Aleurone—A stored protein found as cytoplasmic inclusion in seeds like castor, maize etc.

Zymogen—Inactive precursor of an enzyme (i.e. a proenzyme) stored in the cells of digestive glands as a cytoplasmic inclusion.

Cystolith—A specialised excretory cytoplasmic inclusion of plants which is made up of aggregated crystals of calcium carbonate.

Raphide—A specialised excretory cytoplasmic inclusion of plants which is made up of aggregated crystals of calcium oxalate.

Lithocysts-Specialised and enlarged plant cells that contain raphide.

Laticifers-Specialised cells or ducts of plants, containing latex (or plant milk).

2.23. Nucleus

Definition: The nucleus is the most important membrane enclosed part of the eukaryotic cells, which contains chromosomes and controls all the activities of the cell.

Robert Brown, a botanist, first noticed the presence of nucleus in the cells of orchid leaves and named it in 1831.

Distribution: All eukaryotic cells except mature mammalian RBC and sieve tubes in phloem of plants contain nucleus. Generally, it is located at the centre of the cells but in a few cases, it may occupy a peripheral position. For example-in mature plant cells, with increase of size of the vacuole, the nucleus along with the cytoplasm is pushed peripherally; in adipose tissue of animals, the nucleus is also pushed toward one end of the cell by the accumulating bulk of fat; the nucleus of skeletal muscle cells are also located just beneath the cell membrane.

Number: Generally, each cell contains a single nucleus; but in certain animal cells (e.g. Paramoecium, cartilage cells, cardiac muscle cells etc.) and plants cells (e.g. alga like Vaucheria, fungus like Rhizopus, cells of latex vessels etc.), more than

one nuclei are present.

Multinucleated animal cells (i.e. a mass of protoplasm containing many nuclei that are not separated by membranous partitions) are called syncitial cells, whereas such plant cells are called coenocytes.

Origin: Nuclei originate from the pre-existing ones and are never formed de nevo or afresh. During cell division, the nucleus of the mother cell divides to form the daughter

nuclei.

Size: The nucleus is the largest of all cellular organelles and its diameter varies from 5-25 μm . The size of the nucleus is proportional to the chromosome number. Thus, in haploid cells, the size of the nucleus is smaller than that of the diploid cells. In each somatic cell, during the interphase (or the period of non-division), the nucleus attains a specific size that depends on the DNA and protein content and also on the functional activity of the nucleus.

In growing cells, the volumes of the nucleus and the cytoplasm are in equilibrium and their relationship is expressed by the nucleoplasmic (or nucleocytoplasmic) index

which is the ratio of the nuclear volume to cytoplasmic volume. Thus, $NP = \frac{Vn}{Vc + Vn}$; where NP is the nucleocytoplasmic index, Vn is the nuclear volume and Vc is the cell volume.

Types: Depending upon the number, size and nature of nucleus, the cells may be of the following kinds :-

[1] Eukaryon--It is a cell containing a single nucleus.

[2] Dikaryon-It is a cell containing two nuclei of the same kind. It is also called homokaryon.

[3] Polykaryon-It is a cell that contains several nuclei of the same type.

[4] Heterokaryon-It is a single cell containing nuclei of two types, produced by fusion of two cells.

[5] Synkaryon-It is a hybrid cell line generated by a heterokaryon whose nuclei have entered mitosis synchronously and merged i.e. by karyogamy of a heterokaryon.

Again, the nucleus itself may be of the following types depending on its nature :-

[1] Amphinucleus-It is a diploid type of nucleus which contains two sets of genome. It is found in somatic cells.

[2] Heminucleus-It is a haploid type of nucleus containing only one set of genome.

This type of nucleus is found in gametes.

[3] Pronucleus-The haploid nucleus of an ovum or spermatozoon, present in a fertilized ovum before their fusion, is called pronucleus. The nucleus of an ovum before it unites with that of the spermatozoon which has penetrated it is called **female pronucleus**. The nucleus of the spermatozoon after it has penetrated an ovum is called **male pronucleus**.

[4] Micronucleus and Macronucleus—In a dikaryon (or a cell containing two nuclei of same type), the two nuclei are unequl in size. Among these, the smaller one is called

micronucleus and the bigger one is called macronucleus or meganucleus.

Shape: The nucleus of majority of cells is spherical or oval. Nevertheless, the shape of nucleus may vary in certain cells; for example—disc-like (squamous epithelium), pyriform or kidney shaped (monocyte-WBC, Paramoecium), C-shaped (Vorticella), monoliform or like a string of beads (Spirostomum), lobed (neutrophil-WBC) etc. The shape of the nucleus is sometimes related to that of the cell. In spheroidal, cuboidal, or polyhedral cells, the nucleus is generally spheridal whereas in cylindrial, prismatic or fusiform cells, the nucleus is usually ellipsoidal.

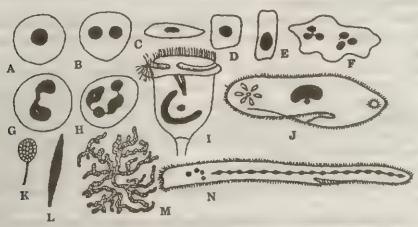


Fig. 2.54: Variation in the shape and number of nucleus in different cells.

A-mononucleate cell, B-binucleate cell, C disce shaped nucleus, D-spherical nucleus, E oval nucleus, F-polynucleate cell, G-bilobed nucleus, H-multilobed nucleus, I-'C' shaped nucleus (Vorticella).

J-pyriform or kidney shaped nucleus (Paramoecium), K-elliptical nucleus (Sperm), L spindle shaped nucleus (sperm), M-labyrinthine (branched) nucleus (Platyphylax), N-monoliform nucleus (Spirostomum)

Ultrastructure: A typical nucleus consists of four parts [1] nuclear membrane, [2] nucleoplasm, [3] chromatin reticulum and [4] nucleolus,

[1] Nuclear membrane: The membranous covering of the nucleus is called nuclear membrane or nuclear envelope or karyotheca. It is a double membrane structure comprising of an outer and an inner membrane, each being a trilamellar (P-L-P) unit membrane. These two membranes remian separated by a space called perinuclear space or perinuclear cisternae which is about 10-15 nm in width. The nuclear membrane originates from the endoplasmic reticulum (ER) and remains connected with it so that the perinuclear space is continuous with the space inside the cisternae and tubules of the ER. The outer membrane is rough surfaced due to the presence of ribosomes on it. The nuclear membrane possesses numerous pores called nuclear pores. The outer and inner membranes fuse with each other at the circumference of the pores. The nuclear membrane separates the nuclear material from the cytoplasm and gives the shape of the nucleus. The pores present in it allow the necessary exchange of materials between nuclear material and cytoplasm. The number of pores is about 40-

145/µm² in the nuclei of various plants and animals. The pores are not simple opening but are plugged with a hollow cylinder of proteinaceous materials called annulus, which extends both into the cytoplasm and nucleoplasm. The pore and the annulus together constitute a pore complex. Exchange of materials through the pore complex is mediated by a protein called nucleoplasmin present in the nucleus.

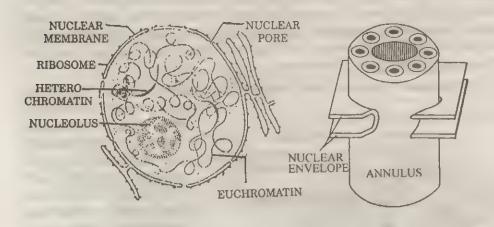


Fig. 2.55: Structure of nucleus

Fig. 2.56: The nuclear pore and annulus

- [2] Nucleoplasm: The transparent, finely granular and slightly acidophilic colloidal semifluid ground substance of the nucleus is called nucleoplasm or nuclear sup or karyolymph. It remains surrounded by the nuclear mambrane. Nuclear components such as the chromatin reticulum and the nucleolus remain suspended within this semifluid material. It is composed of RNA, DNA, protein, enzymes, coenzymes and minerals. The nucleoplasm functions as the matrix or ground substance of the nucleus.
- [3] Chromatin reticulum: The coiled network like structure formed by the nucleoprotein threads present in the nucleoplasm is called charomatin reticulum. These nucleoprotein threads are called chromatin fibres. During the interphase or resting phase (when the cell is not undergoing divisions), the chromatin fibres form a coiled network. During cell division, the chromatin fibres become dense and divided into a definite number of short, thick, thread of rod like structures called chromosomes. The chromatin threads are composed of DNA and basic histone proteins. The DNA is the bearer of hereditary characters. Due to the presence of DNA in the chromatin threads, they readily take basic stains. Based on this fact, the term chromatin has been derived (Gr. chroma = colour). Depending on the staining properties, the chromatin reticulum is divisible into two parts—(i) euchromatin and (ii) heterochromatin.
- (i) Euchromatin: The region of chromatin reticulum which takes a light stain in resting cells and a comparatively deeper stain during cell division is called euchromatin. During resting phase, it remains thin, less coiled and extended, whereas during cell division, it becomes condensed, tightly coiled and thick. This is why the euchromatin

takes a light and deep stain during resting and dividing conditions of the cell respectively. Due to the presence of large quantities of DNA in it, the euchromatin functions as the chief carrier and transmitter of hereditary characters. It takes an active part in the production of mRNA and thereby protein synthesis. Crossing over occurs in this region.

(ii) Heterochromatin: The portion of chromatin reticulum which is darkly stained in both resting as well as dividing conditions of a cell is called heterochromatin. It remains condensed, tightly coiled and thick in both resting and dividing cells; hence it always takes a deep stain. It contains only small amount of DNA, which is not very active. Thus, the heterochromatin is much less important for heredity as well as synthesis of mRNA and proteins. In this part, crossing over does not occur to a great extent; thus it protects the 'vital genes' from crossing over.

[4] Nucleolus: The small, dense, highly stainable and refractive, spherical or oval

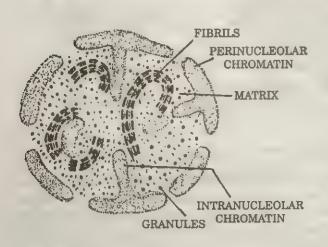


Fig. 2.57: Structure of nucleolus.

body present in the nucleus of non-dividing cells is called nucleolus. Generally, each cell contains a single nucleolus, but in certain cells e.g. some liver cells, lymphocytes, etc. more than one nucleoli may be present. nucleolus is not externally bound by a membrane. It becomes most conspicuous during protein synthesis. It disappears during cell division and reappears division is after the completed. The nucleolus is

composed mainly of RNA and proteins. It is divisible into four parts as follows-

- (i) Pars amorpha or Matrix—It is the homogenous ground substance made up of proteins within which granules and fibrils remain scattered.
- (li) Pars granulosa—This granular portion is made up of ribonucleoprotein (RNA-protein) granules of about 150-200Å diameter. The ratio of protein: RNA in these granules is 2:1. Since, these granules are similar to the ribosomes present in the cytoplasm, they may also be called nuclear ribosomes. In fact, these nuclear ribosomes are the precursor of cytoplasmic ribosomes.
- (iii) Fibrillar part-This part is composed of fine ribonucleoprotein fibrils and is also called nucleolonema. Probably the granular part originates form these fibrils.
- (iv) Chromatin part—The nucleolus contains chromatin material made up of DNA. The chromatin which surrounds the nucleolus like a shell is called perinucleolar chromatin. It may be like a continuous thick wall or thin and porous. From this, some trabecular projections enter at places and form the intranucleolar chromatin. The DNA present in the chromatin region of nucleolus takes part in the synthesis of ribosomal

RNA (rRNA). On the whole, the function of nucleolus is to take an active part in the synthesis of rRNA and proteins and thereby formation of ribosomes.

Functions of nucleus:

- [1] Nucleus is the most vital centre of the cell and it regulates all the activities of the cell. Hence, the nucleus is considered as the 'brain of the cell'.
- [2] It plays an important role in the production of RNA, ribosome and protein,
- [3] It takes a major part in cell division.
- [4] Due to the presence of DNA (the genetic material) in it, the nucleus functions as the mediator of heredity.

REVISION

Nucleus—The membrane enclosed part of a cell which contains the genetic material and controls all the activities of the cytoplasm.

Syncitium-A multinucleated animal cell.

Coenocyte-A multinucleated plant cell.

Nuclear envelope or Nuclear membrane or Karyotheca-The double membrane covering of the nucleus.

Nuclear pore or Nucleopore-Interruption in the nuclear envelope that allows exchange of materials between the nucleus and the cytoplasm.

Annulus-A hollow cylindrical proteinaceous material enclosing the nuclear pores.

Pore complex-A complex structure formed by the nuclear pore and annulus.

Perinuclear cisternae or Perinuclear space—The space enclosed within the two membranes of the nuclear envelope.

Nucleoplasm or Nuclear sap or Karyoplasm-The semifluid ground substance of the nucleus.

Chromatin-The complex of DNA and proteins.

Nucleolus—The spherical or oval structure present within the nucleus which consists of chromatin and large amount of RNA and acts as the site of rRNA synthesis and ribosome formation.

• Why is the nucleus considered as the 'brain of the cell' and how was it proved?

The nucleus of a cell is considered as the brain of the cell because the nucleus is the most vital part of the cell and it controls all the activities of the cell. This was proved by two classical experiments, one conducted by **Balbiani** on an animal cell and the other by **Hammerling on a plant cell**.

Balbiani carried out an experiment called merotomy on an unicellular animal Amoeba proteus (a protozoa). In this experiment, the cells of Amoeba proteus were

enucleated (i.e. their nuclei were removed) and as a result, all the cellular activities of the organisms ceased, eventually leading to death of the organism.

Hammerling performed a similar experiment on the cells of Acetabularia, a mushroom shaped marine alga which is a large unicellular plant. In this experiment, the cells of Acetabularia were cut into two pieces—a lower rhizoidal part containing the nucleus and an upper head (or cap) portion devoid of the nucleus. The nucleated rhizoidal part survived and formed a complete new plant, while the non-nucleated cap portion did not survive.

• How was it proved that the nucleus controls the morphological characters of a cell?

This was proved by Hammerling's classical experiment on nuclear grafting between two species of Acetabularia called Acetabularia crenulata (AC) and Acetabularia mediterranea (AM) whose cap (or head) portions are morphologically different. In this experiment (Fig. 2.58), each of the AC and AM was cut into three pieces—an upper cap part, a middle stalk part and a lower rhizoid part. Among these three parts, only the rhizoid part contained the nucleus of the Acetabularia cell (or plant). When the stalk of AM was grafted on the rhizoid of AC, a complete new plant grew, whose cap portion was morphologically similar to that of AC. Conversely, when the stalk of AC was grafted on the rhizoid of AM, the newly developed cap looked like that of AM. Again when the rhizoids of the two species were joined by grafting, an intermediate type of plant was developed. These findings clearly showed that the nucleus controls the morphological chracters of a cell.

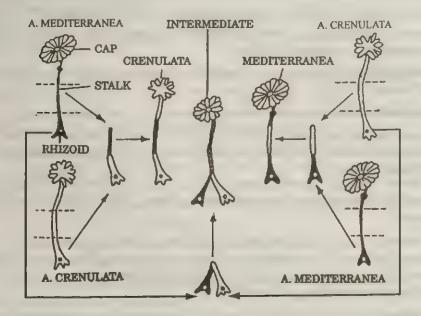


Fig. 2.58: Hammerling's experiment on Acetabularia.

• Summary of the location, structure and function of different parts of eukaryotic cells

Name of the part	Location and Structure	Function
1. Cell membrane or Plasmalemma or Plasma membrane	It is located at the boundary of the cytoplasm. It is a thin, living membrane made up of lipoprotein. It is a trilamellar protein-lipid-protein (P-L-P) structure having pores. It is a selectively permeable membrane.	It (i) gives a shape to the cell; (ii) protects the cytoplasmic organelles; (iii) helps in exchange of materials between ECF and ICF; (iv) maintains excitability of the cells and connection between the cells; (v) gives origin to membranous
2. Cell Wall (In plant cells only)	It is located outside the cell membrane of plant cells. It is a thick. rigid, non-living covering made up of carbohydrates mainly cellulose and also hemicellulose, pectin, lignin, suberin etc. It consists of three layers—middle lamella, primary wall and secondary wall from outside inwards. It contains fine pores through which cytoplasmic connections called plasmodesmata are established	organelles. It (i) maintains the shape of a cell; (ii) gives mechanical strength to the cell; (iii) helps in exchange of materials between cytoplasm and the surrounding fluid; (iv) acts as a waterproof layer and conserves water in some cells.
3. Cell Coat or Glycocalyx (In some animal cells only)	between the adjacent cells. It is located as an external covering around the cell membrane of some animal cells. It is made up of glycoproteins (mucopolysaccharides) and glycolipids. It is thought to be a secretory product of cytoplasm.	It (i) gives mechanical protection to the cell; (ii) forms a microenvironment for the cell (iii) helps in cell recognition; (iv) gives antigenicity to the RBCs
4. Nucleus	Almost all living cells contain at least one nucleus. It is usually spherical or oval in shape and is located at the centre of the cell. However, its shape, size, number and location may vary from cell to cell. The nucleus is made up of four partsnuclear membrane, nucleoplasm, nucleolus and chromatin reticulum. The chromatin reticulum contains DNA, the genetic material.	(iii) It plays the main rol in cell division; (iv)

Name of the part	Location and Structure	Function
5. Cytosol	It is the fluid matrix part of cytoplasm and is also called hyaloplasm or cytoplasmic matrix in which the cytoplasmic organelles and cytoplasmic inclusions remain suspended. It contains various inorganic and organic materials.	It (i) holds the organelles and inclusions of the cell; (ii) maintains the colloidal properties of protoplasm; (iii) maintains the internal milleu of the cell; (iv) carries out various metabolic functions.
6. Mitochondria	These are double membrane bound small vesicular structures having spheroidal, oval or rod-like shape. They are found in variable numbers in a cell and remain scattered in the cytoplasm. The inner membrane is folded that divides the organelle into some incompletely partitioned compartments. They contain respiratory and other enzymes.	(i) It is also called as the power house of the cell because it is the chief cellular site for generation of ATP through TCA cycle, β-oxidation of fatty acids, ETS and oxidative phosphorylation. (ii) It carries out fatty acid systhesis and production of DNA, RNA and some proteins.
7. Endoplasmic reticulum (ER)	It remains extended from the cell membrane to nuclear membrane. It is a membrane bound, network like vacuolar system made up of stacked, flattened, sac-like cisternae, tubules and small vesicles. Numerous ribosomes remain attached to the outer surface of cisternae, hence they appear to be rough surfaced. ER is of two types—smooth ER (SER) and rough surfaced ER (RER). The RER is made up of cisternae while the SER is made up of tubules mainly.	It (i) gives origin to the nucleus and Golgi body; (ii) helps in protein and lipid synthesis; (iv) helps in exchange of materials between ECF and ICF; (iv) helps in excitation contraction coupling in muscles; (v) gives mechanical support to the cytoplasm.
8. Ribosomes	These are granular bodies made up of RNA and protein and are not bounded by a membrane. They remain freely scattered in the cytoplasm or attached to the ER cisternae and nuclear membrane.	These are concerned with protein synthesis; hence they are also called protein factory of the cell.

Name of the part	Location and Structure	Function
9. Golgi body 10. Lysosomes (In animal cells only)	It is also a membrane bound vacuolar system that is connected to the ER. It is located at one side of the cell in between the cell membrane and the nuclear membrane. It is made up of stacks of curved cisternae, vacuoles and tubules that remain interconnected. The Golgi-cistemae are devoid of ribosomes and hence smooth surfaced. These are unit membrane bound vesicles containing hydrolytic enzymes. They remain scattered in the cytoplasm. They are of two main types-primary lysosomes and secondary lysosomes (autophagosomes and heterophagosomes).	It helps in— (i) secretion of cells; (ii) glycoprotein formation; (iii) formation of cell membrane, cell wall and lysosome; (iv) formation of acrosomal cap of sperms. They help in (i) intracellular digestion of phagocytosed materials or defunct organelles; (ii) autolysis of the whole cell for tissue regression; (iiii) extracellular digestion.
12. Centrosome (In animal cells mainly)		They (i) form the frame work of cytoplasm that gives mechanical support to it; (ii) help in cell movement of various kinds. It helps in formation of (i) spindle fibres during cell division; (ii) motile structures of the cells like cilia, flagella and sperm tail.
13. Plastids (In plant cells only)	the centrosphere. Each centriole is a cylindrical structure, the wall of which is made up of 9 triplet microtubules.	Chloroplasts take part in photosynthesis. Chromoplasts impart colour to plant organs for attraction of insects and birds for pollination and dispersal of seeds. Leucoplasts help in storage of food.

Name of the part	Location and Structure	Function
5. Cytosol	It is the fluid matrix part of cytoplasm and is also called hyaloplasm or cytoplasmic matrix in which the cytoplasmic organelles and cytoplasmic inclusions remain suspended. It contains various inorganic and organic materials.	It (i) holds the organelles and inclusions of the cell; (ii) maintains the colloidal properties of protoplasm; (iii) maintains the internal milleu of the cell; (iv) carries out various metabolic functions.
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11. Cytoskeleton 12. Centrosome (In animal cells mainly)	at one side of the nucleus. At the time of cell division, it divides into two centrosomes that remain at two opposite poles of the cell. It consists of a pair of centrioles lying at right angles to each other and the cytoplasm covering them, the centrosphere. Each centriole is a	extracellular digestion. They (i) form the frame work of cytoplasm that gives mechanical support to it; (ii) help in cell movement of various kinds. It helps in formation of (i) spindle fibres during cell division; (ii) motile structures of the cells like cilia, flagella and sperm tail.
13. Plastids (In plant cells only)	cylindrical structure, the wall of which is made up of 9 triplet microtubules. These are found in the cytoplasm of all eukaryotic plant cells except the fungi. They are double membrane bound organelles containing pigments or stored food. They are of 3 types-chloroplasts (that contain the green pigment chlorophyll), chromoplasts (that contain non-greeen pigments like xanthophyll and carotenoids) and leucoplasts (that contain stored food but no pigment).	Chloroplasts take part in photosynthesis. Chromoplasts impart colour to plant organs for attraction of insects and birds for pollination and dispersal of seeds. Leucoplasts help in storage of food.

Name of the part	Location and Structure	Function
14. Vacuoles (In plant cells mainly)	These are membrane bound spaces within cytoplasm. They contain a fluid (cell-sap) or gas or oil. The thin membrane covering the vacuole is called tonoplast (or tonoplasm). Protozoans may also contain small vacuoles.	organs of the cells that store metabolic waste products or food. The gas-vacuoles found in
15. Cytoplasmic inclusions or Ergastic substances	These are the non-living materials that remain scattered in the cytoplasm of the cells. They may be of 4 major types—stored food, secretory matters, excretory matters and pigments.	

2.24. A Few Comparisons

Prokaryotic cell

● Difference between Prokaryotic and Eukaryotic cells ●

1. N	Vucleus
Due to lack of nuclear membrane, a true nucleus is not at all formed in it. The nuclear material remains scattered in the cytoplasm and is not digtinguishable from it. The nuclear material is called nucleoid . Nucleolus is absent in such a primitive nucleus or nucleoid.	A well developed nuclear membrane is present which separates the nuclear material from the cytoplasm. The nuclear membrane is made up of two concentric membranes, each of which is an unit membrane (P-L-P). The nuclear membrane has many pores in it. The nucleus contains a well organised nucleolus. Thus, a true nucleus is formed in these cells.

2. Chromosome

In these cells, true chromosomes are not formed. The nuclear material is made up of a DNA fibre only, which is not associated with a basic histone protein. The DNA thread divides by binary fission.

In these cells, the chromatin material forms a definite number of chromosomes that are made up of DNA and a basic histone protein. The chromosomes divide by a process of mitosis or meiosis.

Eukaryotic cell

3. Plastid

Plastids are not found in these cells. The photosynthetic pigments and enzymes are stored in the lamellae present in the cytoplasm or the chroma-tophores attached to cell membrane.

In eukaryotic plant cells, a specialised organelle called plastid is found within which photosynthetic pigments and enzymes are stored in membrane enclosed form.

Prokaryotic cell

Eukaryotic cell

4. Other membrane bound organelles:

In these cells, other unit membrane bound organelles e.g. mitochondria, endoplasmic reticulum, Golgi body, lysosome etc. are not found.

In these cells, well organised and membrane bound organelles e.g. mitochondria, endoplasmic reticulum, Golgi body, lysosomes etc. are present for performing specialised functions.

5. Ribosome

Ribosomes are present in these cells as the site of protein synthesis. But these ribosomes are much smaller in size (70S type) than the ribosomes present in eukaryotic cells. These ribosomes remain freely scattered in the cytoplasm and not associated with a membranous organelle (because such organelles are not at all formed in these cells).

Ribosomes present in these cells are comparatively larger in size (80S type). They mainly remain attached to the outer surface of the rough surfaced endoplasmic reticulum and the nuclear membrane. Some smaller ribosomes (55S type) are also present within mitochondria and plastids or scattered freely in the cytoplasm.

6. Cell Wall

Some prokaryotic cells possess a cell wall. The cell wall is made up of nitrogen containing complex compounds of mucopeptide nature.

Only the eukaryotic plant cells possess a cell wall, which is made up of carbohydrates, mainly cellulose.

7. Flagella

Flagella simple, 9 + 2 organisation absent.

Flagella specialised and show 9 + 2 organisation.

8. Microtubules

Absent

Present

9. Pilli

Different kinds of pilli present

Pilli absent.

● Difference between Plant cell and Animal cell ●

Plant cell

Animal cell

1. Cell wall

Plant cells possess a cell wall made up of cellulose, outside the cell membrane.

Animal cells are devoid of the cell wall.

2. Plastid

These cells contain plastids. Most of the plant cells possess chloroplasts (green pigment chlorophyll containing plastid) by virtue of which they are capable of synthesising their own food (glucose) by photosynthesis.

Animal cells do not possess plastids and as a result they are unable to synthesise their own food by photosynthesis.

Plant cell

Animal cell

3. Vacuole

The vacuoles are found mainly in plant cells where they (vacuoles) are comparatively much larger in size and more in number Higher animal cells do not contain vacuoles. I ower animal cells may possess vacuoles, but of much smaller size and only a few in number.

4. Centrosome

Plant cells are devoid of centrosome

Centrosome is present in animal cells.

5. Lysosome

These are absent in plant cells.

Lysosomes are present in animal cells.

6. Microvilli

Plant cells do not possess microvilli

Microvilli are seen in some animal cells

7. Intercellular connections

Adjacent cells are interconnected by cytoplasmic continuity called *plasmodesmata*

Plasmodesmata are absent *i.e.* there is no cytoplasmic continuity between the adjacent cells. But the cell membranes of the adjacent cells may come in close contact at places to form desmosomes, tight junctions *etc.* that make intercellular connections.

8. Cytokinesis

Cytokinesis is initiated by the formation of cell plate

Cytokinesis is initiated by the formation of a groove in the middle of the cell membrane on both side of the equatorial plane.

Difference between Somatic cell and Germ cell

Somatic cell	Germ cell		
1. Chromosome number			
It is a diploid cell	It is a hapleid cell		
2. 0	ccurrence		
It is found in different organs of the	It is found only in reproductive organs		
body	of the body		
3. 1	functions		
It takes part in body growth	It takes part in sexual reproduction		
4	Types		
It may be of various kinds depending	It may be of two sexully different kinds		
on the organ in which it is present.	only (male and female types).		

Difference between Cell membrane and Cell wall .

Cell membrane Cell wall 1. Distribution It is found in both animal cells and plant It occurs only in plant cells (absent in cells animal cells) 2. Location It is located just outside the cytoplasm Cell wall is located outside the cell and surrounds the cytoplasm. membrane surrounding it. 3. Nature It is a thin and clastic living membrane It is a thick and rigid non-living covering. 4. Structure It is made up of lipoprotein. (1) It is made up of carbohydrates, (ii) It is trilamellar; the three layers mainly cellulose and pectin (ii) It is also trilamellar; the layers are arranged as protein-lipid-protein. from outside inwards are-middle lamella, primary wall and secondary wall (iii) Microvilli may be present in it. (iii) Microvilli are never present. 5. Functions (i) It is semipermeable. It is permeable (ii) It gives rigidity to the cell (ii) It does not give rigidity to the cell. (iii) It does not take part in the (iii) It takes part in the formation of formation of cell organelles. various cell organelles. (iv) It has no role in pinocytosis or (iv) It takes part in pinocytosis and phagocytosis or any such activity. phagocytosis.

Difference between Phagocytosis and Pinocytosis

Phagocytosis	Pinocytosis
1. It is the process of engulfing of solid particles or large colloidal particles by the cell (i.e. cell eating) 2. In this, the cell surface produces numerous pseudopodia around the particle to be engulfed, and a phagocytic vesicle or phagosome is formed by fusion of the tips of the pseudopodia	1. It is the process of active make of fluid by the cell (i.e. cell drinking) 2 In this, the cell surface invaginates to form narrow channels from the inner end of which fluid containing small vesicles or pinosomes are pinched off into the cytoplasm.

● Difference between Prokaryotic ribosomes and Eukaryotic ribosomes ●

Prokaryotic ribosomes	Eukaryotic ribosomes
1. These are <i>smaller</i> in size and are of 70S	1. These are <i>larger</i> in size and are of 80S
type having subunits 50S + 30S.	type having subunits 60S + 40S
2. Remain freely scattered in the	2. Remain attached to the outer membrane
cytoplasm.	of rough endoplasmic reticulum and nucleus.
3. Cleft between the subunits is relatively	Cleft between the subunits is relatively
deeper.	- less deep.
4. RNA: Protein ratio is 2:1.	less deep. 4. RNA: Protein ratios is 1:1.

• Difference between SER and RER •

SER	RER
1	. Loçation
Close to cell membrane.	Close to the nucleus.
2.	Occurrence
Lipid and steroid forming cells and striated muscles.	Protein secreting cells.
3.	Structure
(i) Does not contain ribosomes.	(i) Contains ribosomes.
(ii) Made up of tubules.	(ii) Made up of cisternae.
4	. Function
Synthesis of lipids and steroids; glycogenolysis; detoxication etc.	Synthesis of proteins.

• Difference between Ribosome and Lysosome •

Ribosome	Lysosome		
1. Distribution			
It is found in prokaryotic as well as eukaryotic (both plant and animal) cells.	It is found only in eukaryotic cells (mainly animal cells).		
2. Lo	cation		
It is mainly found to be attached on the endoplasmic reticulum and nucular membrane; also found within some organelles or freely scattered in the cytoplasm.	It is found mainly in freely scattered form in the cytoplasm (not associated with an organelle).		
3. Stri	ucture		
(i) It is a solid granular organelle which is not covered by a membrane. (ii) It is made up of two subunits. (iii) It is frequently found in groups called polyribosome.	(1) It is a membrane enclosed, fluid filled organelle. (i1) It is not divisible into subunits. (iii) It is always found singly (not in groups).		
It functions as the site of portein synthesis.	It is concerned mainly with hydrolytic processes.		

● Difference between Endoplasmic reticulum and Golgi body ●

Endoplasmic reticulum

Golgi body

1. Location

It extends from cell membrane to nuclear membrane.

It is generally located near the nucleus.

2. Structure

- (i) Its shape does not change from time to time.
- (11) It may be smooth or rough surfaced depending on absence or presence of ribosomes on it respectively.
- (i) Its structure may change from time to time.
- (ii) It is only smooth surfaced because of the absence of ribosomes on its surface.

3. Functions

- (1) Due to the presence of ribosomes, the rough surfaced endoplasmic reticulum takes part in protein synthesis.
- (ii) It helps in the formation of nuclear membrane and Golgi body.
- (i) Being devoid of ribosomes it does not take part in protein synthesis.
- (ii) It helps in the formation of cell membrane, cell wall and lysosomes.

• Difference between Mitochondria and Plastids •

Mitochondria

Plastids

1. Distribution

These are found in both plant and animal cells. These are found only in plant cells.

2. Types

Mitochondria are not distinguishable into different types.

Plastids are of three types-chloroplast, chromoplast and leucoplast.

3. Structure

- (i) These are double membrane bound, pigment (colour) less organelles.
- (ii) From the inner membranes of these, finger like projections called cristae are extended towards the matrix. The cristae divide the organelle into several chambers.
- (i) These are also double membrane bound organelles that may be pigmented (coloured, e.g. chloroplast and chromoplast) or pigment less (e.g. leucoplast).
- (ii) The inner membrane does not form cristae. But some membranous disc-like structures called thylakoids remain piled to form grana.

4. Function

- (i) They take part in cellular respiration.
- (ii) They play no role in manufacture of food by photosynthesis and its storage.
- (iii) They do not determine the colour of the organism.
- (iv) They help in catabolism and oxidation of food stuff for release of energy; hence they are called power house of the cells.
- (i) These are not related to cellular respiration.
- (ii) Chloroplasts manufacture food by photosynthesis, and leucoplasts store food.
- (iii) Chloroplasts and chromoplasts determine the colour of various plant organs.
- (iv) They help in anabolism or synthesis of food (glucose) and thereby captures the solar energy and stores it in the cells; hence these are also called kitchen of the cells.

actively.

◆ Comparison between Chloroplast, Chromoplast and Leucoplast

Comparison Source		
Chloroplast	Chromoplast	Leucoplast
1. Location: It is found in those plant cells which are exposed to sunlight.	It is found in plant cells that may or may not be exposed to sunlight.	It is found in the cells of those parts of a plant that are not exposed to sunlight.
2. Structure: (i) It is green coloured plastid. (ii) It contains thylakoids. (iii) It contains the pigments—chlorophyll and carotenoids. The pigments are stored within the thylakoids.	(i) It is coloured but nongreen plastid. (ii) It contains thylakoids. (iii) It contains carotenoids but not chlorophyll. The pigments are scattered in the matrix.	(i) It is colourless plastid. (ii) It does not contain thylakoids. (iii) It contains no pigment at all.
3. Function: It manufactures the food of plants (glucose) by the process of photosynthesis.	It gives colour to the flower, fruit, root, etc. that attracts insects and birds for pollination and dispersal of seeds. It does not synthesise or store the food of plants.	It does not manufacture food but helps in the storage of food.

plants.			
Difference between Euchromatin and Heterochromatin			
Euchromatin	Heterochromatin		
This part of chromatin fibre takes a lighter stain during interphase (resting or non-dividing condition of the cell) and a deep stain during cell division. 2. Stur	This part of the chromatin fibre takes a deep stain in both resting and dividing cells.		
It remains thin and extended in resting cells, whereas it becomes highly coiled and thick in dividing cells.	It remains highly coiled and thick in both non-dividing as well as dividing cells.		
3 Chemical composition			
It contains large amount of DNA.	It contains comparatively smaller quantity of DNA.		
4. Function			
(i) It is genetically very important and it takes part in the maintenance of heredity. (ii) It takes part in crossing over	 (i) It is genetically not so important and does not take an active part in maintenance of heredity. (ii) In this part, the chance of crossing over is very low. 		

Nucleolus

It is a part of nucleus and remains surrounded

by the nucleoplasm.

1. Location

2. Structure

Nucleus

surrounded by the cytoplasm in a cell.

sensory transduction etc.

It is a part of protoplasm and remains

Difference between Nucleus and Nucleolus

(i) It is not covered by a membrane. (i) It remains covered by a membrane (the nuclear membrane). (ii) The chromatin material present in it (ii) The chromatin material present in it remains like a thick wall. remains as a network or reticulum during resting (non-dividing) condition of a cell and forms a definite number of chromosomes during cell division. (iii) It is made up of RNA and proteins (iii) It is composed of DNA, RNA and mainly (but its chromatin part contains DNA). proteins. 3. Functions (i) It is not directly involved in cell (i) It takes a major part in cell division. division. It disappears during cell division and reappears after the division. (ii) It has no role in heredity. (ii) It helps in transmission of hereditary characters from one generation to the next. (iii) The DNA present in the chromatin (iii) The DNA present in the chromatin material of nucleolus helps in synthesis of reticulum helps in protein synthesis through rRNA and thereby formation of ribosomes and the formation of mRNA. proteins. Difference between Microtubules and Microfilaments Microfilaments Microtubules 1. Structure (i) These are solid structures. (i) These are hollow tube like structures. (ii) They are less wide having a diameter (ii) They are much wider having a diameter of 5-7 nm. of about 25 nm. (iii) Formed by 2 chains of a globular (iii) Formed by 13 protofilaments or chains protein that remain twisted around each of a globular protein that remain spirally arranged around a lumen. 2. Composition These are made up of the proteins actin and These are made of the protein tubulin mainly. myosin mainly. 3. Function (i) They do not take part in the formation (i) They take part in the formation of organelles like centrosome, cilia and flagella. of any organelle. (ii) These are contractile. (ii) These are non-contractile. (iii) Microfilaments are concerned mainly (iii) In addition to the various types of with cell motility of various types e.g. movements in the cell e.g. movement of cilia, amoeboid movements, streaming of cytoplasm, flagella and chromosomes, the microtubules muscle contraction etc. They do not have other also help in many other functions e.g. transport functions like that of microtubules. of macromolecules, change of cell shape,

• Difference between centriole and centromere •

Centrioic	
1. Centriole is a highly specialised	1. Centromere is the unstainable
organelle found in all animal cells and	region in every eukaryotic chromosome
in motile vegetative and reproductive	somewhat smaller in diameter than the
cells of several plants.	remainder of the chromosome.

2. It serves in intracytoplasmic anchoring of the microtubules of cilia and flagella. It also acts as the organisational centre of the spindle apparatus.

Contriole

2. It aids attachment chromosomes with the spindle apparatus during mitosis and meiosis.

Centromere

● Difference between Ectoplasm and Endoplasm ●

Ectoplasm	Endoplasm
1. It is the peripheral narrow part of	I. It is the inner major part of
cytoplasm. 2. It is more transparent and non-	cytoplasm. 2. It is less transparent and more
granular. 3. It is more viscous and rigid.	granular. 3. It is less viscous and less rigid.

3. It is more viscous and rigid.	3. It is less viscous and less rigid.	
● Difference between Cytoplasm and Nucleoplasm ●		
Cytoplasm	Nucleoplasm	
1. Log	cation	
It is located in between the nuclear membrane and cell membrane, i.e. outside the nucleus.	It is located in the area surrounded by nuclear membrane, i.e. within the nucleus.	
2. Division		
It is divisible into two main parts- ectoplasm and endoplasm.	It is not divisible into different parts.	
3. Composition and structure		
(i) It is a highly granular colloidal semifluid. (ii) All the cell organelles are present in it. (iii) It may contain vacuoles and may show cyclosis.	(i) It is a less granular colloidal semifluid. (ii) Only the nuclear components like nucleolus, chromatin and some free ribosomes remain suspended in it. (iii) It does not contain vacuoles, hence does not show cyclosis.	

4. Function

It acts as the site of numerous biochemical processes.

It acts as the ground substance or matrix of the nucleus.

Difference between Nucleoplasm and Hyaloplasm

Hyaloplasm Nucleoplasm 1. Nature It is the cytoplasmic matrix. It is the nuclear matrix. 2. Location It is located outside the nucleus in It is located within the nucleus, covered between the nuclear membrane and cell by the nuclear membrane. membrane. 3. Division It has two main divisions -outer It has no divisions. ecotoplasm and inner endoplasm. 4. Composition and structure (i) It does not contain DNA. (i) It contains DNA. (ii) All the cell organelles remain (ii) Only nucleolus, chromatin and some free ribosomes remain suspended suspended in it. in it. 5. Function It carries out the metabolic processes It does not carry out metabolic process like glycolysis, fatty acid synthesis etc. like glycolysis, fatty acid synthesis etc. Difference between Nucleus (or Eukaryotic nucleus) and Nucleoid (or Prokaryotic nucleus) Nucleoid (Prokaryotic nucleus) Nucleus (Eukaryotic nucleus) 1. Occurrence It is found in prokaryotic cells. It is found in eukaryotic cells. 2. Structure (i) Not distinctly separate from the (i) Distinctly separate from the cytoplasm. cytoplasm. (ii) Made up of a DNA fibre only. (ii) Made up of four parts-nuclear membrane, nucleoplasm, nucleolus and chromatin reticulum. (iii) Definite number of chromosomes (iii) Definite number of chromosomes are not formed. are formed. (iv) Its DNA does not remain (iv) Its DNA remains associated with associated with histone protein. a basic histone protein. 3. Division

It divides by amitosis, mitosis and

meiosis.

It divides by binary fission.

Difference between Lysosome and Lysozyme

Lysosome	Lysozyme
1. It is found in animal cells.	1. It is found in fluids of animal body
	like tear, saliva etc.
2. It is a membrane bound vesicular	2. It is a bacteriolytic enzyme.
cell organelle filled with hydrolytic	
enzymes.	
3. It is concerned with intracellular	3. It is concerned with defence
and extracellular digestion, tissue	mechanism and innate immunity of
regression etc. in animals.	animals.

regression etc. in animals.	animals.	
Difference between Microsomes and Microbodies		
Microsomes	Microbodies	
1. 0	rigin	
These are not natural cell organelles but are artifacts produced during cell fractionation.	These are natural cell organelles produced from the endoplasmic reticulum (ER).	
2. Composition/Structure		
They include SER, RER and Golgi bodies, all of which are double membrane bound organelles.	They include peroxisomes and glyoxysomes that are single membrane bound organelles.	
3. Function		
Concerned mainly with protein synthesis.	Concerned mainly with metabolism of hydrogen peroxide and lipids.	

• Difference between Glyoxysome and Peroxisomes •

Glyoxysomes	Peroxisomes		
1. Occurrence			
These are found in plant cells only.	These are found in both plant cells and animal cells.		
2. Contents			
They contain enzymes for β-oxidation of fatty acids and glyoxylate cycle.	They contain oxidative enzymes like peroxidase, catalase <i>etc</i> .		
3 Function			

3. Function

They are involved in metabolism of stored lipids and their conversion to carbohydrates. They help in germination of oil bearing seeds.

They are involved in metabolism of hydrogen peroxide. They help in photorespiration in plants.

• Difference between Lysosome and Spherosome •

Lysosome Spherosome Spherosome

These are found in animal cells only.

These are found in plant cells only.

2. Contents

1. Occurrence

They contain numerous hydrolytic enzymes.

They contain lipid synthesising enzymes in addition to the hydrolytic enzymes.

3. Function

They take part in extracellular and intracellular digestion, tissue regression *etc.* in animals.

They help in synthesis, storage and metabolism of lipids in plants.

• Difference between Glycosomes and Glyoxysomes •

Glycosomes	Glyoxysomes		
1. Occu	1. Occurrence		
These are found in the liver cells (i.e. in animals).	These are found in plant cells, particularly in oil rich endosperm tissues of seeds.		
2. Contents and Function			
They contain glycogen and help in glycogen storage.	They contain enzymes for β-oxidation of fatty acids and glyoxylate cycle and help in conversion of stored lipids to carbohydrates.		

Difference between Lysosomes and Peroxisomes

Lysosome	Peroxisome
1. 000	urrence
They occur in animal cells only.	They occur in both animal cells and plant cells.
2. Co	ontents
They contain various types of hydrolytic enzymes.	They contain oxidative enzymes related to hydrogen peroxide.
Fur	nction

They help in intracellular as well as extracellular digestion, tissue regression etc.

They help in formation and breakdown of hydrogen peroxide. In plant cells, they help in photorespiration.

2.25. Matters to Recollect

- Cell is the structural and functional unit of life.
- R. Virchow proposed that cells originate from pre-existing cells.
- Anton Van Leuwenhock first observed living cells under microscope.
- Dougherty classified cells into prokaryotic and eukaryotic types.
- Cells having a membrane-enclosed, well developed nucleus are eukaryotic whereas those lacking it, are prokaryotic.
- Nucleus is the 'brain of the cell'.
- Protoplasm is colloidal in nature.
- Protoplasm is the physical basis of life.
- The smallest unicellular organism is Mycoplasma.
- The largest unicellular plant is Acetabularia.
- The largest animal cell is egg of ostrich and longest cell is neurone.
- The largest plant cell is the bark fibre of Ramie.
- Virus is a non-cellular living organism.
- The P-L-P membrane is called unit membrane (Robertson).
- The cellulose wall outside the cell membrane of plant cells is called cell wall.
- Plasmodesmata are cytoplasmic continuity between the adjacent plant cells.
- The common cell wall between adjacent plant cells is called middle lamella.
- Protoplasm minus nucleus is cytoplasm.
- The soluble fraction of cytoplasm is called cytosol or hyaloplasm.
- Living structures suspended in cytosol are called cytoplasmic organelles and non-living particles of cytoplasm are called ergastic substances or cytoplasmic inclusions.
- Mitochondria are the 'power house' of a cell.
- Lysosomes are 'suicide bags' of a cell.
- When many ribosomes are linked by a single mRNA, it is called polysome or polyribosome.
- Ribosome is the 'protein factory' of a cell.
- Plastids are double membrane bound organelles, containing pigment or food.
- Plastids containing the green pigment chlorophyll are chloroplasts.
- Non-green, coloured plastids are called chromoplasts.
- Chloroplast is the 'kitchen' of a cell.
- Colourless plastids are called leucoplasts.
- Fluid present in vacuoles is called **cell sap** and its membranous covering is called **tonoplast.**
- Engulfing of solid and liquid materials by a cell are called phagocytosis and pinocytosis respectively.

2.26. Summary

Study of cells is based on use of certain tools (like different kinds of microscopes) and techniques (like cell fractionation and tracer techniques). All living organisms are made up of one or many cells(s). Cell is the structural and functional unit of life and is made up of protoplasm surrounded by a semipermeable membrane. Protoplasm is the physical basis of life because this colloidal semifluid material exhibits all the characters of life. Cells may be of different size and shape. Depending on the organisation of the nucleus, they are divided into two main groups—prokaryotic and eukaryotic.

Prokaryotic cells: These are primitive cells in which the nucleus is not well organised due to the lack of a nuclear membrane. Other membrane bound cytoplasmic organelles *e.g.* mitochondria, Golgi body, endoplasmic reticulum *etc.* are also absent in these cells. Examples of this type of cells are bacteria, blue green

algae etc.

Eukaryotic cells: Cells having a well organised, membrane bound nucleus are called eukaryotic. Various membrane bound cytoplasmic organelles are also found in these cells. Eukaryotic cells are of two types plant cells and animal cells. Such cells are made up of two parts—the cell covering and the protoplasm. In animal cells, the cell covering is a lipoprotein membrane called cell membrane or plasmalemma. It is a trilamellar (protein-lipid-protein) membrane having pores in it. It separates the protoplasm from the ECF and functions as a selectively permeable membrane through which exchange of materials between the two fluids occur. Plant cells also possess a plasmalemma which is externally covered by an additional rigid cellulose covering called cell wall. It is also porous and through these pores cytoplasmic bridges called plasmodesmata are formed between the adjacent cells. The cell wall is permeable and gives mechanical support to the cell.

The protoplasm of eukaryotic cells is distinguished into two parts—cytoplasm and nucleus. Cytoplasm is a clear but granular semifluid extending from the plasmalemma to the nuclear membrane. It is made up of three parts—cytosol, cytoplasmic organelles and cytoplasmic inclusion. The watery matrix or soluble portion of the cytoplasm is called cytosol or hyaloplasm in which the other two components remain suspended. The living structural elements suspended in the cytosol are called cytoplasmic organelles that are generally bound by a trilamellar (P-L-P) membrane similar to the plasmalemma. Such P-L-P membranes are called unit membranes. Cytoplasmic organelles are as follows:

Mitochondria—These are spherical or oval or rod-like, double membrane bound structures, the inner membrane of which is folded inward to divide the cavity of the organelle into a few chambers. They carry out cellular respiration (i.e. oxidation of food stuff) to yield energy. Hence, these are called 'power house' of a cell.

Endoplasmic reticulum (ER)—This is a tubular network, extending from the plasmalemma to the nuclear membrane. It may be rough or smooth surfaced depending on the presence or absence of ribosome particles on it. The rough surfaced reticulum is the site of protein synthesis, whereas the smooth ones help in transport of materials and informations.

In certain cells, the ER may become modified to form different sturctures like sarcoplasmic reticulum, myeloid body, annulate lamella, glycosomes and microbodies.

Ribosomes-These are particles made up of RNA and protein that remain freely scattered in the cytoplasm or bound to the membrane of rough endoplasmic reticulum and nucleus. These are the sites of protein synthesis.

Golgi body-It looks like a stack of unit membrane bound, flattened and curved

sacs having a smooth surface. It is related to secretory function of a cell.

Lysosome-It is found only in animal cells. It is a membrane bound vesicular organelle containing several hydrolytic enzymes that help in intracellular and extracellular digestion as well as autolysis of dead organelles and cells. Thus, it is also called 'suicide bag' of the cell.

Cytoskeleton-Certain protein made fine filamentous structures form the framework of cytoplasm; they are collectively called cytoskeleton. It includes

microtubules, microfilaments and intermediate filaments.

Microtubules are hollow cylinder-like structures made up of a globular protein called tubulin. They may remain scattered in the cytoplasm as temporary structures concerned with transport of macromolecules within the cells or they may remain in bundles to form some specialised permanent structures, e.g. centrosomes, cilia and flagella.

Centrosome is found in animal cells only and not in plant cells. It is made up of two parts-a pair of centrioles and centrosphere. Centriole is a barrel shaped microtubular structure that forms spindle during cell division. Centrosphere is the

cytoplasmic covering around the centrioles.

Cilia and flagella are microtubular projections from the cell surface that are concerned with cell motility. Cilia are short and numerous while flagella are few

and long.

Microfilaments are solid structures made up of proteins like actin, myosin, tropomyosin, troponin and α-actinin. They occur beneath the cell membrane or in the deeper parts of cytoplasm. In addition to formation of cytoskeleton, the microfilaments help in many functions, e.g. cytoplasmic streaming, amoeboid movement, muscle contraction and various other movements of the cell membrane.

Intermediate filaments are of four types-keratin filaments, neurofilaments, glial filaments and heterogenous filaments. They are made up of proteins like desmin,

vimentin and synemin. They give mechanical support to the cell.

Plastids-These are found in plant cells only, and are of three types-chloroplasts, chromoplasts and leucoplasts. Chloroplasts are chlorophyll (green pigment) containing plastids that carry out photosynthesis. Since it stores the solar energy in the form of chemical energy, it is also called 'transducer of plants'. Chromoplasts are non-green, coloured plastids that impart colour to various parts of a plant. Leucoplasts are colourless plastids that store food materials.

Vacuole-It is an apparently empty space in the cytoplasm which remains filled with a fluid called cell sap. It is found mainly in plant cells. The vacuoles of plant cells are much larger in number and size than those of animal cells. It stores food or

excretory or secretory materials.

Several non-living materials are scattered in the cytoplasm; these are called cytoplasmic inclusions or ergastic substances. Three types of such substances e.g. stored food, secretory matters and excretory products are found in the cells. Each cell generally contains a single (in some cases more than one) nucleus which is located at the centre of the cell. It is made up of chromatin network, nucleolus, nuclear sap and nuclear membrane. This controls the overall activity of a cell.

2.27. Naming/Discovery/Discoverer

- [1] Compound microscope discovered by F. Janssen and Z. Janssen (1590)
- [2] Electron microscope discoverd by Knoll and Ruska (1931).
- [3] Cell discovered and named by Robert Hooke (1665).
- [4] The name protoplasm given by Purkinje (1839).
- [5] Cell theory proposed by M. J. Schleiden and T. Schwann (1838-1839).
- [6] Cell membrane first observed by Nageli and Cramer (1856).
- [7] The name plasmalemma introduced by Plowe (1931).
- [8] The term unit membrane proposed by Robertson (1959).
- [9] The trulamellar model of cell membrane proposed by Danielli and Davson (1935).
- [10] The fluid mosaic model of cell membrane proposed by Singer and Nicolson (1972).
- [11] Cell wall discovered by Robert Hooke (1665) while he discovered cell.
- [12] Plasmodesmata named by Strassburger (1960).
- [13] Mitochondria first observed in the cells of striated muscles by Kolliker (1850), and named by C. Benda (1897).
- [14] Mitochondrial cristae first observed by G. E. Palade (1952).
- [15] Endoplasmic reticulum discovered and named by K. R. Porter et. al (1945).
- [16] Ribosome discovered by A. Claude (1943) and named by G. E. Palade (1955).
- [17] Golgi body discovered by Camillo Golgi (1898).
- [18] Microtubule discovered by De Robertis and Franchi (1953).
- [19] Centrosome discovered and named by Boveri (1888).
- [20] Lysosome-discovered by C. De Duve (1949).
- [21] Plastid-discovered by Schimper (1883).
- [22] Quantosomes (in chloroplast) discovered by Park and Pon (1960).
- [23] Nucleus discovered by Robert Brown (1831).
- [24] Nucleolus-discovered by Wagner (1832).
- [25] The technique of *cell fractionation by ultracentrifugation* discovered by **T. Svedberg** (1938).
- [26] Phagocytosis discovered by Metchnikoff (1882).
- [27] Pinocytosis-discovereed by W. H. Lewis (1931).

2.28. Answers to Special Questions

[1] (a) Who discovered microscope?

(J.E.E. 1996)

(b) Who discovered electron microscope?

(J.E.E. 1994)

- Ans. (a) Francis Janssen and Zacharias Janssen, the two spectacle sellers of Holland discovered microscope in 1590.
 - (b) Electron microscope was discovered by Knoll and Ruska in 1931.
- [2] (a) What is the resolving power of (i) human eye, (ii) light refracting microscope, (iii) electron microscopee? (b) What are the smallest and largest organism on earth? (J.E.E. 1989)
 - Ans. (a) (i) 0.1 mm (or 100 μm); (ii) 0.2 μm (or 200 nm); (iii) 0.5 nm.
 - (b) Smallest organism Mycoplasma; Largest organism Blue whale.

(J.E.E. 1991) Who first discovered/described the cell? [3] Name the scientist who first introduced the name cell? (J.E.E. 1998) Ans. Robert Hooke, a British scientist, first named and described 'cell' in 1665. (J.E.E. 1984) Give two examples of prokaryotic cells. [4] Name two types of organisms who have prokaryotic cells. (J.E.E. 2001) Ans. Bacteria and Blue green algae. Name two types of essential secretory products of protoplasm. [5] (J.E.E. 1984) Ans. Zymogens and hormones. [6] (a) Name two trace elements of protoplasm. (b) What are the main organic (J.E.E. 1988) compounds of protoplasm? Ans. (a) Iron (Fe) and Manganese (Mn). (b) Proteins, nucleoproteins, carbohydrates, lipids, enzymes, hormones and vitamins. (J.E.E. 1998) [7] What is plasma membrane? Ans. The thin, elastic and semipermeable living membrane that surrounds the protoplasm of a cell is called plasma membrane or plasmalemma or cell membrane. [8] (a) What is the main function of plasma membrane? (b) Who first discovered the following? (i) Unit membrane, (ii) Mitochondria, (iii) Nucleus. (J.E.E. 1992) And. (a) The main function of plasma membrane is to serve as an osmotic barrier between the interior and exterior of a cell. It serves as a selectively permeable membrane that separates the protoplasm from the extracellular fluid and at the same time helps in exchange of materials between them. (b) (i) Robertson (1959) (ii) Benda (1897) (iii) Robert Brown (1831). (J.E.E. 1984; 2001) [9] What is phagocytosis? Ans. Phagocytosis means 'eating of cells', i.e. active engulfing of a solid particle into the cell by invagination of the cell membrane. Thus, the particle is incorporated within the cell in a membrane bound vesicular form known as phagocytic vacuole or phagosome. (J.E.E. 1985)[10] What is pinocytosis? Ans. Pinocytosis means 'drinking of cells', i.e. active intake of a fluid. The cell membrane invaginates to form a narrow channel, the pinocytic channel, within which the fluid enters. Then from the inner end of the channel, small fluid filled vesicles are pinched off one by one into the cytoplasm. (J.E.E. 1996) What is reverse pinocytosis? [11] Ans. Reverse pinocytosis is opposite of pinocytosis or vomiting of cells. It is also called 'emeiocytosis'. For this, the membrane covering of a vesicle fuses with the cell membrane to extrude the contents of the vesicle leaving the cell membrane intact. (J.E.E. 1990) Define cell wall. [12] Ans. Cell wall is the semi-rigid, laminated, non-living cellulose covering present

outside the cell membrane of all plant cells and bacteria.

[13] (a) Name two components of a bacterial cell wall which are not present in the cell wall of higher plant. (b) Name the internal membrane present in the prokaryotic cell. (J.E.E. 1996)

Ans. (a) Mucopeptide and peptidoglycan.

(b) Mesosome in bacteria and lamellae (or thylakoid).

[14] (a) Who first showed the presence of mitochondria in living cells? (b) State its function in respiration? (J.E.E. 1984)

Ans. (a) Kolliker (1850) first showed the presence of mitochondria in living cells (striated muscle cells).

(b) Mitochondria helps in aerobic cellular respiration by carrying out TCA cycle, β-oxidation of fatty acids, electron transport and oxidative phosphorylation.

[15] (a) What is rough ER? (J.E.E. 1996, '98) (b) Why is it so named?

(J.E.E. 1998)

Ans. (a) The endoplasmic reticulum (ER) containing ribosomes on their surface is called rough ER. It is made up of a network of inter-communicating cisternae having ribosomes on their surface.

(b) It is so named because its surface appears to be rough and granular due

to the presence of ribosomes.

[16] In which type of cells rough surfaced endoplasmic reticulum is found? (b)

Name the cells where endoplasmic reticulum is absent. (c) State the
functions of endoplasmic reticulum. (J.E.E. 1986)

Ans. (a) Rough endoplasmic reticulum is found in those cells, which are actively synthesising proteins e.g. cells of liver, pancreas etc.

(b) Endoplasmic reticulum is absent in prokaryotic cells, cells of fungi and lower plants, and animal cells like ovum, mature mammalian RBC etc.

(c) Functions of ER: -

(i) Forms a fine network in cytoplasm that gives mechanical support to thee cytoplasmic matrix. (ii) Helps in formation of nuclear membrane, Golgi body and cell wall. (iii) Provides large surface area of membrane for exchange of materials between cytoplasm and extracellular fluid. (iv) Helps in synthesis of proteins, lipids, steroids and lipoproteins. (v) Concerned with glycogenolysis and detoxication.

[17] (a) What is ribosome?

(J.E.E. 1986, '91)

(b) Where is it found?

(J.E.E. 1986)

Ans. (a) Ribosomes are small, dense, granular, non-membranous organelles that are made up of ribonucleoprotein, and concerned with protein synthesis.

(b) Ribosomes are found in all living cells. In prokaryotic cells, they occur freely in the cytoplasm. In eukaryotic cells, they either occur freely in the cytoplasm or remain attached to the outer surface of the ER or nuclear membrane.

18] In 70S ribosomes, what does the letter S stand for? (J.E.E. 1991)

Ans. 'S' stands for Sedimentation co-efficient or Svedberg units.

[19] How does secretion take place by means of Golgi body? (J.E.E. 1987)

Ans. The Golgi body helps in secretion of protein materials from the cell by the process of reverse pinocytosis. After being synthesised in the RER, the secretory proteins pass into the cisternae of Golgi body through the tubules and are stored

in the Golgi vacuoles. From here, the secretory materials are released into the cytoplasm in the form of minute, membrane bound, vesicles which finally fuse with the cell membrane to expel the contents of the vesicle, keeping the cell membrane intact.

[20] Mention one major role of Golgi apparatus.

Ans. The Golgi apparatus is mainly concerned with the formation and packaging of materials for export (secretion) from the cell across the cell membrane by the process of reverse pinocytosis.

[21] (a) What is centrosome? (b) Where is it found? (J.E.E. 1996)

Ans. (a) Centrosome is a spherical mass of dense cytoplasm, containing a pair of cylindrical bodies called centriole, that are concerned with spindle formation during cell division.

(b) Centrosome is found in most of the animal cells. It is located in the

cytoplasm very close to the nucleus.

[22] State the functions of centriole.

Ans. Centrioles help in :-(i) formation of spindle during cell division and movement of chromosomes towards the poles during anaphase; (ii) formation of kinetosome from which cilia and flagella originate and (iii) formation of microtubules.

[23] (a) What is lysosome? (J.E.E. 1994, '96) (b) Where from lysosome is originated? (J.E.E. 1994) (c) Mention its functions. (J.E.E. 1994, '96)

Ans. (a) Lysosome is a membrane bound vesicular cytoplasmic organelle containing hydrolytic enzymes.

(b) Lysosomes originate from the Golgi body by cutting off the Golgi

vesicles filled with hydrolytic enzymes.

(c) Functions of Lysosomes:—(i) Intracellular digestion of materials taken in by phagocytosis or pinocytosis, (ii) Regression of defunct and old tissues by autolysis due to rupture of lysosomal membrane so that the entire cell is self digested. (iii) Extracellular digestion by secreting lysosomal enzymes into the surrounding.

[24] Where are the chlorophyll molecules concentrated in the chloroplasts?
(J.E.E. 1983, '85)

Ans. In chloroplasts, the chlorophyll molecules remain concentrated within qunatosomes, the spheroidal bodies, present within the disc-like structure called thylakoids that form the grana.

[25] Name one cell organelle with single layered membrane and another with double layered membrane.

(J.E.E. 1996)

Ans. Single layered Golgi body or Endoplasmic reticulum or lysosome (any one of these). Double layered-Mitochondria or Plastid (any one).

[26] Why does betacyanin pigment come out of beet root when warmed, but carotene from boiled carrot does not?

Ans. Betacyanin is a water soluble pigment present in the cell sap. It comes out on warming because warming causes damage of the cell membrane. On the other hand, carotene is a water insoluble pigment present in plastids; so, it does not come out even on boiling.

[27] Name each part of a well developed nucleus. (J.E.E. 1985)

Ans. A typical nucleus consists of four parts (i) nuclear membrane, (ii) nucleoplasm, (iii) chromatin reticulum and (iv) nucleolus.

[28] (a) In which stage the nuclear membrane is absent in a cell? (b) Where is rRNA synthesised? (c) Where does citric acid cycle take place.

(J.E.E. 1987)

Ans. (a) Late prophase or early telophase (b) Nucleolus (c) Mitochondria.

- [29] (a) How many membranes comprise the nuclear envelope? (b) What are nucleosomes? (J.E.E. 1992)

 Ans. (a) Nuclear envelop comprises of two membranes (b) Nucleosomes are ultrastructural building units of chromosomes, visible only under electron inicroscope and are composed of certain length of the DNA and a basic histone protein.
- [30] (a) Name the different types of RNA. (b) State the functions of each.

 (J.E.E. 1991)
 - Ans. (a) (i) Messenger RNA (mRNA), (ii) Transfer RNA (tRNA) or Soluble RNA (sRNA) and (iii) Ribosomal RNA (or rRNA)
 - (b) Functions: (i) mRNA-It carries the codon or the genetic information present in the DNA and directs the cell about what type of protein (enzyme) is to be synthesized in the cell by working as the template for protein synthesis. (ii) tRNA-It binds with the specific amino acid and carries it to the ribosomes (or the site of protein synthesis) according to the anticodon which it bears. (iii) rRNA-It is involved in the integrity and functioning of the ribosomes and mRNA so that they can form the template for protein synthesis.
- [31] What is rhizoplast? Where is it found? (J.E.E. 1985)

 Ans. Rhizoplast is the nucrotubular connection between basal body and centrosome. It is found in *Chlamydomonas*.
- [32] Where ribosomes and lysosomes are formed? Mention two functions of each. (J.E.E. 1998)

Ans. Ribosome: Formation—Ribosomes are formed in both prokaryotic and eukaryotic cells. In prokaryotic cells, ribosomes are formed in the cytoplasm by the action of nucleoid. In eukaryotic cells, ribosomes are formed by the joint action of nucleolus and cytoplasm.

Function—(i) Protein synthesis: (ii) Fatty acid synthesis.

Lysosomes: Formation-Lysosomes are formed in the cytoplasm by the action of Golgi body.

Function- (i) Intracellular digestion; (ii) Autolysis of cells.

[33] (a) From which structure within the cell the lysosomes originate? (b) What is autophagosome? (c) How is the cell protected from the destructive enzymes contained within the lysosome? (d) What are ribophorins?

(J.E.E. 1998)

Ans. (a) Golgi body.

- (b) Autophagosomes are secondary lysosomes formed by fusion of a primary lysosome with a senile and defunct cell organelle.
- (c) The cell is protected from the destructive enzymes contained within the lysosome because these enzymes remain covered within the lysosomal

membrane and they do not come in contact with the other cell contents.

(d) Ribophorins are two glycoproteins (called ribophorin I and ribophorin II) present in the ER-membrane, which have specific affinity to ribosomes. These proteins help to bind the ribosomes with the ER.

[34] State the differences between the nucleus of bacteria and nucleus of yeast. (J.E.E. 1995)

Ans.

Alls.	
Nucleus of bacteria	Nucleus of yeast
 Nucleus is ill developed and it is called nucleoid. It contains only nucleic acid (DNA). 	 Nucleus is well developed and called true nucleus. It contains nuclear membrane, nucleoplasm, nuclear reticulum and
3. In this, the proportion of nucleic acid and protein is unequal.	nucleolus. 3. In this, the proportion of nucleic acid and protein is equal.

- [35] (a) What is pleomorphism? (b) What is tonoplasm? (c) What is polyribosome? (d) What is inulin? (e) What is coenocyte? (J.E.E. 1999)
 - Ans. (a) Pleomorphism means ability of an organism or cell to occur in various morphologically distinct forms or ability to change the shape of an organism.
 - (b) Tonoplasm is the membranous covering of the large central vacuole of the mature plant cells.
 - (c) Polyribosome is a cluster of several ribosomes attached to a single mRNA, that serves as a translational unit.
 - (d) Inulin is a fructan *i.e.* polysaccharide formed by several fructose units; it is found in the root of *Dahlia*.
 - (e) Coenocyte is a multinucleated plant cell.
- [36] Mention where tonoplast is found?

(J.E.E. 1999)

Ans. Tonoplast (or tonoplasm) is the membranous covering found in mature plant cells, around the large central vacuole.

- [37] (a) What is the chemical component of the wall of the pollen that resists decay during fossilisation? (b) What are the three chemical classes of pigments that impart colour to floral parts? (J.E.E. 1994)
 - Ans. (a) Sporopollenin. (b) Flavonoids, carotenoids and betalins.
- [38] Mention two factors on which red and blue colour of flowers depend.
 (J.E.E. 1994)

Ans. (i) pH of the cell sap and (ii) Anthocyanin pigment.

- [39] Name one plant cell and one animal cell where nucleus is absent.

 Ans. Plant cell-sieve tube; Animal cell-matured mammalian RBC.
- [40] Which cell organelles are found in plant cells only?

 Ans. Plastids, dictyosomes, glyoxysomes.

[41] What is the function of dictyosome?

Ans. Dictyosome is the Golgi body of plant cells and it helps in the secretory process of the plant cells.

- [42] (a) Name the organelle in which Krebs cycle occurs? (b) In which tissues it is very abundant?
 - Ans. (a) Mitochondria, (b) Liver and cardiac muscle.
- [43] What are grana?

Ans. Grana are specialised structures present in the chloroplasts. They are made up of stacks of membrane bound flattened sacs called thylakoids within which chlorophyll is stored.

- [44] (a) Where is nucleolus located? (b) Write its functions.
 - Ans. (a) Nucleous is located within the nucleus.
 - (b) It is concerned with synthesis of rRNA and thereby formation of ribosomes.
- [45] (a) What is leucoplast? (b) What is its function.
 - Ans. (a) Leucoplasts are colourless plastids which do not contain pigment.
 - (b) It stores food materials like starch, proteins and oils.
- [46] What is raphide?

Ans. Raphides are specialised excretory cytoplasmic inclusions of plant cells formed by aggregated crystals of *calcium oxalate*. They may be of two types-sphaeraphides (star shaped) and acicular raphides (which look like a bunch of fine needles).

[47] What is cystolith?

Ans. Cystoliths are specialised excretory cytoplasmic inclusions of plant cells that are made up of aggregated *calcium carbonate* crystals and look like bunch of grapes.

- [48] In which type of cells, cell wall is present?
 - Ans. Cell wall is present in all plant cells except the gametes.
- [49] What are lithocysts and idioblasts?

Ans. Lithocysts are specialised and enlarged plant cells that contain cystoliths whereas idioblasts are specialised plant cells that contain raphides.

- [50] Which organelle/part of the cell is considered as the following and why?(i) Power house of a cell; (ii) Protein factory of a cell, (iii) Suicide bag of a cell. (iv) Kitchen of the cell, (v) Plant lysosomes and (vi) Brain of the cell.
 - Ans. (i) Mitochondrion is considered as power house of a cell because it takes part in cellular respiration and thereby generates ATP, the energy currency of a cell.
 - (ii) Ribosome is also called 'protein factory' of a cell because it forms the template for protein synthesis and acts as the cellular site for protein synthesis.
 - (iii) Lysosome is considered as the *suicide bag* of the cell because this bag -like organelle may cause autolysis or self-digestion of the whole cell.
 - (iv) Chloroplast is called kitchen of the cell because in this organelle, the food of the plant (sugar) is prepared from raw materials (CO₂ and H₂O) by the process of photosynthesis.
 - (v) Spherosome is also considered as plant lysosome because like the

lysosome found in animal cells, the spherosome is also small, single membrane bound vesicular organelle filled with hydrolytic enzymes.

(v1) Nucleus is called 'brain of the cell' because it controls all the activities

of the cell.

[51] Why chloroplast is called transducer of plants?

Ans. Transducer is a device which converts one form of energy to another. Chloroplast is called transducer of plants because it carries out photosynthesis in which the solar radiant energy is converted to chemical energy.

[52] What are the following?

- (i) Claude's particle, (ii) Lipochondria, (iii) Zone of exclusion, (iv) Mitoribosome, (v) Residual body, (vi) Basal body, (vii) Axoneme.
- Ans. (i) Claude's particle is the other name of ribosomes.

(ii) Lipochondria is the other name of Golgi body.

(iii) Zone of exclusion is the region of cytoplasm surrounding the Golgi body, where no other cell organelle is found.

(iv) Mitoribosomes are mitochondrial ribosomes of 55 S type.

- (v) Residual body is a remnant of the heterophagosomes, within which some residue is left for excretion.
- (vi) Basal body is the part of cilia or flagella lying below the level of cell membrane, from which the cilia or flagella proper originates.
 - (vii) Axoneme is the central microtubular bundle of cilia and flagella.
- [53] What do you mean by kinetosome and kinoplasm?

 Ans. Kinetosome is the other name of the basal body of cilia or flagella, whereas kinoplasm is the organising material of centrosome.
- (J.E.E., 1991, 2001)

 Ans. The haipoid nucleus of a sperm or an ovum, present in a fertilized ovum before their fusion, is called pronucleus (male and female pronucleus). The male and female pronucleus fuse to form the zygote (diploid) nucleus.

[55] Which organelle connects cell membrane with nuclear membrane?

(J.E.E. 2000)

Ans. Endoplasmic reticulum.

[56] Name the organelle which contains enzymes responsible for breakdown of macromolecules. (J.E.E. 2000) Ans. Lysosome.

[57] What are the chemical components of nucleoli? (J.E.E. 2000)

Ans. Mainly RNA and protein; some amount of DNA is also present in its chromatin part.

[58] (a) What is ribosome? (b) Where from it originates? (J.E.E. 2000)
Ans. (a) See answer to Q. 17(a).

(a) See answer to Q. 17(a).

(b) Nucleus.

[59] Name the plant cell visible with naked eye.

Ans. Root hair cell or phloem (bark) fibre cell of jute, cotton, etc. (Any one)

[60] Name the cytoplasmic organelles of eukaryotic cell.

Ans. Mitochondrion, Endoplasmic reticulum, Ribosome, Golgi body, Lysosome, Plastid, Centrosome (Microtubule), Vacuole.

- [61] Define euchromatin. Mention its chemical nature. (J.E.E. 2002)

 Ans. The gene-rich functional portion of chromatin, which takes a light stain in resting phase (interphase) and comparatively deeper stain during cell division is called euchromatin. Chemically, it consists of DNA, which is made up of deoxyribose sugar, phosphoric acid and nitrogen bases (adenine, guanine, thymine and cytosine).
- [62] Write the names of different types of waste products of plants with one example of each, mention one use of each.

 (J.E.E. 2002)

 Ans.

Type of waste product	Example	Use (Economic importance)
1. Organic acid	Citric acid	Flavouring of food.
2. Essential oil	Eucalyptol	Used as nasal emollent in various articles of domestic use.
3. Gum	Gum arabic	Used as adhesive.
4. Resin	Shellac	Used in manufacture of paints and varnishes.
5. Latex	Rubber	Used in manufacture of tyres, tubes, balloons.
6. Tannin	Tannic acid	Used in processing of leather and preparation of medicines and writing ink.
7. Glycosides	Digitalin	Used as cardiac medicine.
8. Alkaloids	Quinine	Used as anti-malarial drug.
9. Mineral crystals	Cystolith (calcium carbonate)	It has no economic use.

- [63] What do you mean by cytoskeleton? Name the unit structure forming this cytoskeleton. State its importance. (J.E.E. 2003)
- Ans. Cytoskeleton or skeleton of cells is a network of protein-made, rigid, tubular and filamentous structures that forms the frame work of cytoplasm.

 The cytoskeleton is formed by microtubules (made up of a protein called tubulin) and microfilaments (made up of proteins like actin, myosin, troponin

etc.)
The cytoskeleton gives a shape to the cell. It helps in cellular movements and intracellular transport of materials (macromolecules). They also take part in formation of cilia, flagella, centrosome etc.

[64] Distinguish between starch grain and zymogen grain.

Ans.

	Starch grains	Zymogen grains
1.	These are reserve food stored in plant cells.	These are inactive precursor forms of enzymes stored in animal cells (cells of digestive glands).
2.	These are chemically carbohydrate (polysaccharide).	2. These are chemically proteins.

[65] What is latex? Where does it occur?

Ans. Latex is a white, milky, viscous, colloidal excretory matter of plants. It occurs in specialised cells or ducts called **laticifers** (which may be of two types **latex cells** and **latex vessels**) found in stems and leaves of plants like banyan, jack fruit, papaya etc.

[66] Distinguish between microtubule and endoplasmic reticulum.

Ans.

Microtubule	Endoplasmic reticulum
1. Structure :	1. Structure:
(i) It is a part of cytoskeleton.	(i) It is a part of vacuolar system of cell.
(ii) It is a hollow tubular structure	(ii) It is a hollow structure containing
made up of a protein tubulin. It is not	tubules, cisternae and vesicles. It is unit
membrane found.	membrane bound structure made up of protein and lipid (P-L-P).
(iii) Ribosomes are not attached to it.	(iii) Ribosomes may remain attached
	to it.
2. Function:	2. Function:
(i) Gives shape of the cell.	(i) Gives mechanical support to cytoplasm.
(ii) Takes part in formation of cilia,	(ii) Takes part in formation of nuclear
flagella and centrosome.	membrane and Golgi body.
(iii) Helps in cell movement.	(iii) It has metabolic functions, e.g. synthesis of protein and lipids, glycogenolysis etc.

[67] Write a brief note on cystolith.

Ans. Cystolith is an excretory product of plants, made up of aggregates of calcium carbonate crystals, looking like bunch of grapes. It is found in specialised cells called **lithocysts** present in leaves of plants like banyan, fig, rubber etc. It has no economic use.

[68] Distinguish between organ and organelle.

Ans. Organs are structural components of multicellular plant and animal bodies. They are macroscopic structures. Organelles are structural components of a cell, *i.e.* the subcellular particles. They are microscopic structures.

[69] Write a short note on mitochondria.

Ans. Mitochondria (sing. mitochondrion) are double membrane bound organelles of eukaryotic cells. They are usually rod-like but they may also be spherical, oval or filamentous in shape. The inner membrane is folded to form cristae, that divide the interior of mitochondria into several incompletely partitioned chambers, filled with a matrix. The cristae and matrix of mitochondria contain various enzymes that carry out differnt metabolic processes. The main function of mitochondria is cellular respiration and generation of ATP from oxidation of food. So mitochondria are considered as 'power house' of the cell.

[70] What is middle lamella?

Ans. Middle lamella is a thin layer of jelly-like, viscous, intercellular matrix present in between two adjacent plant cells, that bind them like a cementing material. It is made up of mainly pectin and small amount of protein.

[71] What is plasmodesmata?

Freev type or I and Answer t

constitute primary cell wall.

[14] What is cell wall? How does it differ from cell membrane.

Ans. Plasmodesmata are cytoplasmic bridges between adjacent plant cells. They are fine cytoplasmic canals lined by plasma membrane and passing through the pores of cell wall. They help to maintain continuity of cytoplasm between adjacent plant cells.

[72] Name an animal cell visible with naked eyes.
Ans. Egg of a bird.

[73] Why pinocytosis and phagocytosis are considered as active processes?

Ans. Pinocytosis and phagocytosis are considered as active processes because they require energy expenditure, which is evidenced by a simultaneous increase of O₂ consumption, glucose uptake and glycogen breakdown during these processes. The energy is required for contraction of actin and myosin microfilaments present beneath the cell membrane, which helps in the invagination of cell membrane for these processes.

[74] What is the smallest unit of length used in cytology?

Ans. Angstrom (Å); $1\text{Å} = \frac{1}{10} \text{ nm} = 10^{-7} \text{ mm}.$

EXERCISE

W.	Essay type or Long Answer type:		
[1]	Draw a labelled diagram of a compound microscope (Ans. 2.1.1.A)		
[2]	Write briefly about electron microscope. (Ans. 2.1.1.B)		
EXI			
[4]	What do you mean by a prokaryotic cell? Differentiate it from an eukaryotic cell		
	(Ans. 2.7; 2.24)		
[5]	What is a prokaryotic cell? Draw a labelled sketch of an eukaryotic cell (description not required)		
	Differentiate between these two types of cells [Tripura H.S. 1982] (Ans. 2.7; 2.8; 2.24)		
[6]	Why a cell is called the functional unit of life? Which organelles are found in an eukaryotic cell?		
	Write what you know about an organelle taking part in catabolic process		
	Tripura H.S. 1984] (Ans. 2.3; 2.8; 2.14)		
[7]	Describe the structure of a typical cell with a labelled diagram (Ans. 2.8)		
(8)	What is a cell? Draw a labelleld sketch of a typical plant cell (Ans. 2.3.1; 2.8)		
[9]	What is plasma membrane? [J.E.E. 1998]. Describe its structure and functions (Ans. 2.11)		
[10]	With the help of a diagram describe the unit membrane of Robertson [J.E.E. 1983] (Aus. 2.9)		
[11]	Discuss the functions of cell membrane. [J.E.E. 1979] (Ans. 2.9)		
[12]	In which type of cells, cell wall is present? Describe with diagram the structure of cell wall. What are		
	its functions? (Ans. 2.10)		
[13]	What are the functions of cell wall? What is middle lamella? Name the chemical compounds that		

[15] How cell wall is formed? Describe the structure and chemical nature of cell wall.

[Tripura H.S. 1985] (Ans. 2.10)

[Tripura H.S. 1982] (Ans. 2.10)

[J.E.E. 1990] (Ans. 2.10; 2.24)

[16] What do you mean be thickening of cell wall? Describe the different types of cell wall thickening.

(Ans. 2.10)

[17] What is pit and how many types of pits are there? Describe them. (Ans. 2.10)

[18]	What are cytoplasmic organelles? Write the functions of three such organelles.	9 180
	[J.E.E. 1982] (Ans. 2.13; 2.14; 2.15;	. /
[19]	What are mitochondria? Describe the structure and function of it [J.E.E. 1983] (Ans.	2.14)
[20]	Discuss the structure and function of Golgi body. (Ans.	
[21]	What is Golgi body? Describe its functions. (Ans.	
[22]	(a) What is ribosome? [J.E.E. 1986, '91] (b) Where is it found? [J.E.E. 1986] (c) Describ	e its
	structure and functions. [J.E.E. 1991]. (d) In 70S ribosome, what does the letter S stand for 9 [J	
	1991I (Ans.	
[23]	How many types of endoplasmic reticulum are there? Describe their structure and functions.	
1201	(Ans.	2.15)
[24]	Describe the structure of centrole Mention its functions [J.E.E. 1986] (Ans. 2.19	
		,
[25]		2.20)
[26]	Give a brief description of plastid and mitochondria with diagram and mention their functions.	
	(Ans. 2.20 ;	
[27]	Describe the microscopic structure of chloroplast with diagram. (Ans.	-
[28]	What is vacuole? What is the difference between the vacuoles of plant cell and animal cell? Me	ntion
	the functions of vacuole. (Ans.	2.21)
[29]	What do you mean by ergastic substances of a cell? What are its major types? Give example of	each.
	(Ans.)	2.22)
[30]	Discuss the structure and function of a nucleus. Why it is called most vital centre of the cell?	
	(Ans. :	2.23)
[31]	Write the functions of cell membrane and nucleus. (Ans. 2.9;	
[32]	Where is rRNA synthesised? How does secretion take place by means of Golgi body?	
[34]	[J.E.E. 1987] (Ans. 2.28 Q-28	101
1221		
[33]	What is cell? Draw a labelled sketch of an animal cell. Write the functions of Golgi body and ribos	
	(Ans. 2.3.1; 2.8; 2.17;	
[34]	Write briefly the functions of nucleus and Golgi body. Mention the difference between prokar	
	and eukaryotic cells. (Ans. 2.23; 2.17;	
[35]	(a) Name the different types of RNA (b) State the functions of each type (c) Why does betacy	/anın
	pigment come out of beet root when warmed, but carotene from boiled carrot does not?	
	[J.E.E. 1991] (Ans. 2.28, Q-30	
[36]	[J.E.E. 1991] (Ans. 2.28, Q-30 Write the names of different types of waste products of plants with one example of each, mention	
[36]		one
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B. Sh	Write the names of different types of waste products of plants with one example of each, mention use of each. [J.E.E. 2002] (Ans. 2.28. Contranswer type: What is a cell? What are the major cell types? (Ans. 2.3.1;)-62) 2.7)
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	ONLY OF LIFE 137
[20]	Which cells contain plastid ? Why chloroplasts are green in colour ? (Ans. 2.20)
[21]	In which part of chloroplast the chlorophyll is stored ? [J.E.E. 1983] Or Where are the chlorophyll
	molecules concentrated in the chloroplasts ? [J.E.E. 1985] (Ans. 2.20)
[22]	What is thylakoid and where is it found? (Ans. 20)
[23]	What are grana? (Ans. 2.20)
[24]	(a) What are microtubules? (b) Write their functions. (Ans. 2.19.1)
[25]	Wht is vacuole? Mention different types of it and their functions (Ans. 2.21)
[26]	What is nucleus? Mention its major components. (Ans. 2.23)
[27]	Write the function of dictyosome. [J.E.E. 1989] (Ans. 2.28, Q-41)
[28]	Where is nucleolus located? Write its functions. (Ans. 2.28 Q-44)
[29]	What is leucoplast? What is its function? (Ans. 2.28, Q-45)
[30]	Who discovered light microscope and what was its nature ? [J.E.E. 1991] or, Who discovered
' '	microscope? [J.E.E. 1996] (Ans. 2.1.1)
[31]	Who discovered cell ? [J.E.E. 1991] or Name the scientist who first introduced the name cell
	[J.E.E. 1988] (Ans. 2.28 Q-3)
[32]	What is the main function of plasma membrane? [J.E.E. 1992] (Ans. 2.28 Q-8a)
[33]	What is the function of lysosomal enzymes? [J.E.E. 1992] (Ans. 2.20)
[34]	How many membranes comprise the nuclear envelope? What are nucleosomes?
	[J.E.E. 1992] (Ans. 2.28 Q-29)
[35]	What is nucleoplasm? (Ans. 2.23)
[36]	Who first described or discovered the following?
	(i) unit membrane (ii) mitochondira (iii) nucleus [J.E.E. 1992] (Ans. 2.28 Q-8b)
[37]	Define pinocytosis and phagocytosis [J.E.E. 1992] or What are pinocytosis and phagocytosis?
	[J.E.E. 1986] (Ans. 2.9)
[38]	(a) Who discovered electron microsocope? (b) What is lysosome? Where from lysosome is originated?
	[J.E.E. 1994] (Ans. 2.28 Q-1, 23)
[39]	(a) What are the functions of a centrosome? (b) What is plasma membrane?
	(Ans. 2.19.1A; 2.9)
[40]	(a) Name two components of a bacterial cell wall which are not present in the cell wall of higher plants
	(b) Name one cell organelle with single layered membrane and another with double layered membrane
	(c) Mention one major role of Golgi apparatus. [J.E.E. 1996] (Ans. 2.28 Q-13a, 25, 20)
[41]	(a) What is lysosome? What is its function? (b) What is centrosome? Where is it found? (c) What is
	rough ER? [J.E.E. 1996] (Ans. 2.28 Q-23, 21, 15a)
[42]	What is (i) phagocytosis [J.E.E. 1984], (ii) pinocytosis [J.E.E. 1985], (iii) reverse pinocytosis?
	[J.E.E. 1996] (Ans. 2.28 Q-9, 10, 11)
[43]	Name the internal membrane present in the prokaryotic cell [J.E.E. 1996] (Ans. 2.28 Q-13b)
[44]	(a) Where does nucleolus occur ? (b) What is its major function? [J.E.E. 1996] (Ans. 2.23)
45	(a) What is rough endoplasmic reticulum? Why is it so named? (b) I rom which structure within the
	cell does lysosomes originate "(c) What is autophagosome "(d) How the cell is protected from the
	destructive effects of enzymes contained within the lysosome '(e) What are ribophorins '
***	[J.E.E. 1998] (Ans. 2.28 Q-15, 33)
[46]	Where the tonoplast is found? [J.E.E. 1999] (Ans. 2.28 Q-36)
[47]	(a) What is pleomorphism? (b) What is tonoplasm? (c) What is polyribosome? (d) What is inulin (e) What is coenceyte? [J.E.E. 1999] (Ans. 2.28 Q-35)
1401	(1)
[48]	
[49]	What do you mean by magnifying power and resolving power of a microscope. (Ans. 2.1.2) (a) What is the resolving power of (i) human eye. (ii) light refracting microscope. (iii) electron
[50]	microscope? (b) What are the smallest and largest organisms of earth "[J.E.E. 1989] (Ans. 2.28 Q-2)
(611	Name each part of a well developed nucleus. [J.E.E. 1985] (Ans. 2.28 Q-27)
[51]	(a) In which stage the nuclear membrane is absent in a cell ? (b) Where is rRNA synthesised
[52]	(c) Where does citric acid cycle take place? [J.E.E. 1987] (Ans. 2.28 Q-28)
[53]	What is rhizoplast? Where is it found? [J.E.E. 1985] (Ans. 2.28 Q-31)
[54]	Where ribosome and lysosomes are formed ? Mention two functions of each
[24]	[J.E.E. 1998] (Ans. 2.28 Q-32)
[55]	State the differences between the nucleus of bacteria and nucleus of yeast.
[55]	J.E.E. 1995 (Ans. 2.28 Q-34)
[56]	(a) What is the chemical component of the wall of pollen that resists decay during fossilisation?
[20]	(b) What are the three chemical classes of pigments that impart colour to floral parts?
	(c) Mention two factors on which red and blue colour of the flowers depend?
	[J.E.E. 1994] (Ans. 2.28 Q-37, 38)
	ference and ference

[58] [59]	(a) What is raphide? (b) What is cystohth? What is pronucleus? (a) Which organelle connects cell membrane with nuclear membracentains enzymes responsible for breakdown of macromolecules. (contains enzymes responsible for breakdown of macromolecules. (contains enzymes responsible for breakdown of macromolecules.) [J.E.E.	[J.E.E. 1991] (Ans. 2.28 Q-54) ane? (b) Name the organelle which what are the chemical components, 2000] (Ans. 2.28 Q-55, 56, 57, 58)

	(b) Name the cytoplasmic organelles of editaryone cens	[J.E.E. 2001] (Ans. 2.28 Q-59, 60) [J.E.E. 2002] (Ans. 2.28 Q-61)
[61]	Define euchromatin, Mention its chemical nature Name the unit structure	forming this cytoskeleton. State its

What do you mean by cytoskeleteon? Name the unit structure forming this cytoskeleton. State its [62]

(Ans. 2.28 Q-65) importance. What is latex? Where does it occur?

[63] 164

(a) What is middle lamella? (Ans. 2.28 Q-70,71) (b) What is plasmodesmaia "

· C. Distinguish between:

C. Dist	tinguish between:	J.E.E. 1989, '91, '92] (Ans. 2.24)
111	Prokaryotic and eukaryotic cell	[J.E.E. 1990, '96] (Ans. 2.24]
[1]	Cell membrane and cell wail	(Ans. 2.10)
[2]	Primary cell wall and secondary cell wall	(Ans. 2.11 & 2.10)
[3]	Plasmodesmata and plasmalemma	(Ans. 2.10)
[4] [5]	Simple pit and bordered pit	(Ans. 2.9.1)
[6]	Endocytosis and exocytosis	[J.E.E. 1989, '94] (Ans. 2.24)
[7]	Pinocytosis and phagocytosis	(Ans. 2.24)
[8]	Egtonlasm and endoplasm	(Ans. 2.24)
[9]	Prokaryotic ribosome and eukaryotic ribosome	(Ans. 2.24)
[10]	Ribosome and lysosome	LLE.E. 1993 (Ans. 2.24)
[11]	Centromere and centrosome (or centrole)	(Ans. 2.17 & 2.19.1A)
[12]	Centrosome and Golgi body	(Ans. 2.24)
[13]	Leucoplastic and chloroplastid	(Ans. 2.20)
[14]	Chromoplast and amyloplast	(Ans. 2.24)
[15]	Chloroplastid and chromoplastid	(Ans. 2.22)
[16]	Acicular raphide and sphaeraphide	[J.E.E. 1993] (Ans. 2.24)
[17]	Nucleolus and nucleus	(Ans. 2.23)
[18]	Karyotheca and karyolymph	(Ans. 2.23)
[19]	Chromosome and chromatin	[J.E.E. 1989] (Ans. 2.24)
[20]	Nucleus and and nucleoid	LLE.E. 1985] (Ans. 2.24)
[21]	Plant cell and animal cell	(Ans. 2.20)
[22]	Chloroplast and amyloplast.	(Ans. 2.28 Q-64)
[23]	Starch grain and zymogen grain.	(Ans. 2.24)
[24]	Prokaryotic and eukaryotic nucleus	(Ans. 2.19.1.B.)
[25]	Cilia and flagella	(Ans. 2.24)
[26]	Chromoplast and leucoplast.	(Ans. 2.24)
[27	Germ cell and somatic cell	(Ans. 2.28. Q-66
128	Microtibule and endoplasmic reficultum.	(Ans. 2.24
129	Endoplasmic reticulum and Golgi body.	(Ans. 2.28 Q-68
[30	Organ and organelle.	

• D. Write brief notes :

[1] Prokaryotic cells (Ans. 2.7). [2] Cell theory (Ans. 2.5), [3] Phagocytosis (Ans. 2.9.1), [4] Pinocytosis. (Ans. 2.9.1) [5] Endocytosis and exocytosis. (Ans. 2.9.1) [6] Plasmodesmata. (Ans. 2.10) [7] Secondary cell wall. (Ans. 2.10) [8] Mitochondria (Ans. 2.28 Q-69) [9] Golgi body (Ans. 2.17) [10] Endoplasmic reticulum. (Ans. 2.15) [11] Lysosome. (Ans. 2.18). [12] Centriole (Ans. 2.19. 1A) [13] Plastid (Ans. 2.20). [14] Chloroplast. (Ans. 2.20) [15] Granum (Ans. 2.20). [16] Ergastic substances. (Ans. 2.22) [17] Cellulose (Ans. 2.10). [18] Contractile vacuole (Ans. 2.21). [19] Raphides. (Ans. 2.22). [20] Starch (Ans. 2.22). [21] Nucleus (Ans. 2.23). [22] Nucleolus (Ans. 2.23). [23] Heterochromatin (Ans. 2.23). [24] Euchromatin. (Ans. 2.23). [25] Dictyosome (Ans. 2.17). [26] Nuclear membrane (Ans. 2.23). [27] Zymogen (Ans. 2.22). [28] Cystolith (Ans. 2.28 Q-67).

• E. Complete the sentences with suitable words :

- A zoologist --- and a botanist proposed cell theory. [1] ---- discovered cell. 121
- The prokaryotic cells contain instead of a nucleus. 131
- Blue green algae are —— cells. [4]
- A compound microscope contains and —— lenses for magnification. [5]
- is absent in plant cells and is absent in animal cells 161
- Cristae are found in ---- of cells. [7]
- is called power house of cell. [8]
- Globular structures present on rough endoplasmic reticul in are called --[9]
- produces spindle fibres during cell division. 110]
- Part of cytoplasm surrounding the centrioles is called ----11.11
- [12] Chloroplasts carry out -----.
- [13] is called transducer of plants cells.
- [14] Fluid present in vacuoles is called and the covering of vacuoles is called -
- Nuclear membrane is also called and nucleoplasm is also called [15]
- [16] Chromosomes are present in the ---- of a cell.
- [17] is an unicellular animal.
- [18] Tracers are ----- elements
- [19] --- is the chief constituent of cell wall of eukaryotes.
- [20] Cilia and flagella are made up of -----.

• F. Multiple choice type questions: Select and write the correct answer from those given in the parentheses for completing the following statements.

- Discovery of cell was made by (Dujardin/Robert Hooke Leeuwenhoek/Robert Brown).
- [2] Cell theory was proposed by (Schwann-Schleiden Schleiden).
- [3] The smallest cell is (Mycoplasma/Amocha phage virus).
- [4] The largest cell is —— (hen-egg/tortoise-egg/ostrich-egg).

 [5] The longest cell —— (muscle cell/neurone/cotton fibre)
- [6] A bacterium is a (prokaryotic cell/eukaryotic cell).
- [7] Plasmalemma of animal cell is (non-porous/porous).
- 181 The outermost covering of plant cell is - (cell membrane cell wall). [9] The cytoplasmic continuity between adjacent plant cells is called — (microvilli/plasmalemma/
 - plasmodesmata). [10] Middle lamella is present in between the — (primary walls of two cells/primary and secondary walls
- [11] Cytoplasmic matrix is also called —— (ectoplasm/endoplasm/hyaloplasm)
 - [12] Protein synthesis occurs is -- (lysosome/ribosome/mesosome)
 - [13] The power house of a cell is - (chloroplast/Golgi body/mitochondria).
 - [14] Protein synthesising endoplasmic reticulum is - (smooth surfaced rough surfaced).

 - [15] Centrosome is found in —— (animal cell/plant cell).

 [16] Plastids are found in —— (animal cell/plant cells).
 - The chloroplast of Spirogyra is ——— (cup shaped/nbbon like) [17]
 - Leucoplast helps in ——— (synthesis of food/storage of food) [18]
 - Nucleus was discovered by (Robert Brown/Robert Hooke) [19]
 - [20] Polysaccharide stored in animal cells is ---- (starch glycogen/dextrin)
 - Alcurone granules are --- (lipids/proteins/carbohydrates) [21]
 - Electron transport system is present in - (ribosome mitochondria endoplasmic reticulum/Golgi [22]
 - The chief function of RFR is (proteolysis fat synthesis protein synthesis). [23]
 - Vacuole contains --- (nothing/cell sap). 1241
 - 'Suicide bag' is the term used for (centrosome lysosome mesosome) [25]
 - [26] Cell drinking is termed as (endosmosis/endocytosis pinocytosis)
 - Ribosomes are the centre for —— (protein synthesis respiration/fat synthesis) 1271
 - ---- is exception to cell theory (Bacteria/Virus-l-ungi) [28]
 - Pinocytosis is process (an active/a passive). [29]
 - Adjacent animal cells are connected by (desmosome/polysome/microsome).
 - Adjacent plant cells remain connected by (syncitium/plasmodesmata/plasmalemma) [30]
 - Carotene and xanthophyll are present in —— (amyloplasts/leucoplasts/chromoplasts). 1311 [32]

● G. Put () mark on Yes/No for correct answers:

- [1] Virus is a cell. Yes / No
- [2] Blue green algae are eukaryotic cells. Yes / No
- [3] Robert Hooke discovered cell. Yes / No
- [4] Robert Brown discovered cell. Yes / No
- [5] Bacteria are prokaryotic cells. Yes / No
- [6] Ectoplasm is more granular than endoplasm. Yes / No
- [7] Ribosome is the chief site of lipid synthesis. Yes / No
- [8] Lysosomes are the power house of a cell. Yes / No
- [9] Chloroplast is the kitchen of plant cells. Yes / No
- [10] Mitochondria are suicide bags. Yes / No
- [11] Animal cells contain starch. Yes / No
- [12] RNA is found in cytoplasm. Yes / No
- [13] Rough endoplasmic reticulum contains lysosomes. Yes / No
- [14] Electron microscope has greater magnifying power but less resolution than compound microscope. Yes / No
- [15] All vertebrates are multicellular animals. Yes / No
- [16] Plastids are single membrane bound organelles. Yes / No
- [17] Mitochondria contain enzymes for TCA cycle. Yes / No
- [18] A homogeniser is required for cell fractionation. Yes / No
- [19] Microtubules are made up of the protein actin. Yes / No
- [20] Microfilaments are solid structures. Yes / No

Answers to Q. Nos. E. F. G -

- E. [1] T Schwann, M. J Schleiden [2] Robert Hooke [3] Nucleoid [4] Prokaryotic [5] Eye piece, Objective. [6] Centrosome, Plastid [7] Mitochondria [8] Mitochondrian [9] Ribosome [10] Centriole. [11] Centrosphere. [12] Photosynthesis. [13] Chloroplast [14] Cell sap, Tonoplasm [15] Karyotheca, Karyolymph. [16] Nucleus. [17] Amoeba [18] Isotopic [19] Cellulose. [20] Microtubules.
- F. [1] Robert Hooke. [2] Schwann and Schleiden. [3] Mycoplasma [4] Ostrich egg. [5] Neurone. [6] Prokaryotic cell [7] Porous [8] Cell wall [9] Plasmodesmata. [10] Primary walls of two cells. [11] Hyaloplasm. [12] Ribosome. [13] Mitochondria [14] Rough surfaced [15] Animal cell [16] Plant cell. [17] Ribbon like. [18] Storage of food. [19] Robert Brown [20] Glycogen [21] Proteins [22] Mitochondria. [23] Protein synthesis. [24] Cell sap [25] Lysosome. [26] Pinocytosis [27] Piotein synthesis. [28] Virus [29] An active. [30] Desmosome. [31] Plasmodesmata [32] Chromoplasts.
- G. [1] No. [2] No. [3] Yes. [4] No. [5] Yes. [6] No. [7] No. [8] No. [9] Yes. [10] No. [11] No. [12] Yes. [13] No. [14] No. [15] Yes. [16] No. [17] Yes. [18] Yes. [19] No. [20] Yes.

Cell Function

Topics Discussed: Diffusion; Osmosis, Absorption; Osmoregulation in fresh water and marine animals.

3.1. Diffusion

Definition: Diffusion is a physical process in which molecules or ions of a matter, by virtue of their inherent random motion, migrate from a region of higher concentration to a region of lower concentration.

Explanation or Mechanism of Diffusion:

Molecules of all substances always remain in a state of random linear motion due to the inherent kinetic energy in them. Such molecular motion is maximum in gases, minimum in solids and intermediate in liquids. When two miscible substances (e.g. two gases or two miscible liquids or a liquid and a soluble gas or a liquid and a soluble solid) are kept in contact, the molecules of each spread into the other, due to their inherent motion. Random movement of particles cause a larger number of particles to move from higher concentration to lower concentration than in the reverse direction. So, the net movement of particles would occur from higher to lower concentration. This is called diffusion. Thus, diffusion may occur between gas and gas, liquid and liquid, gas and liquid or solid and liquid; that is to say, diffusion occurs in a gaseous or a liquid medium. Diffusion (movement of molecules from higher to lower concentration) continues until the two substances are uniformly mixed to produce a homogenous mixture. However, the molecular motion in the mixture does not stop even after cessation of diffusion. Diffusion is a passive process because it is not driven by any external force or pressure and it is dependent on the inherent motion of the relevant particles.

The random movement of molecules or ions of any substance is due to their kinetic energy because at any temperature above absolute zero (0° K or -273° C), all components of a matter possess some kinetic energy (i.e. energy of motion or free energy). According to the second law of thermodynamics, the molecular movement of a substance takes place from an area of higher free energy of molecules to an area of lower free energy. Thus, diffusion is due to the **difference in free energy** of the molecules of a substance. The free energy of a substance depends upon—(i) the number of molecules or ions per unit volume and (ii) the rate of motion of the average molecule. Thus, the rate of diffusion of a substance \propto free energy of the substance.

Diffusion pressure (DP):

This can be defined as the potential ability of a gas, liquid or solid to diffuse from an area of its greater concentration to an area of its lesser concentration. In other words, the pressure created by the motion of diffusible particles is called diffusion pressure.

Diffusion pressure is directly proportional to the concentration of (or the number of molecules or ions in) the diffusible material. Therefore, in a diffusion mixture, a region having greater concentration of diffusible material, will exert a higher diffusion

pressure than another region where the concentration of the material is lower. Diffusion is driven by the difference of diffusion pressure (i.e. diffusion pressure gradient) between two regions and in this process, particles move from a place of higher diffusion pressure (concentration) to a place of lower diffusion pressure. In this context, it is important to mention that—(1) diffusion pressure is the cause rather than the effect of diffusion; (ii) diffusion of two materials may occur simultaneously in a common gaseous or liquid medium independent of each other, but the rate of diffusion of these two materials may be different, depending on their concentrations.

The direction of diffusion of one substance is independent of the direction of diffusion of the other substance For example, when diffusion of more than one substances take place in different directions, the movement of each substances is independent of the other. However, the rate of diffusion may slow down to some extent because of collisions between two different kind of particles but their directions remain unchanged. This is why diffusion of oxygen and carbon dioxide occur simultaneously in oppisite directions in the leaves of plants or lungs of animals.

Experiments and Examples of Diffusion:

A few very common and simple experiments (examples) of diffusion are given

[1] If a crystal of copper sulphate is placed in a beaker containing some water, it will be seen that the crystal dissolves slowly and its blue colour spreads in water. So

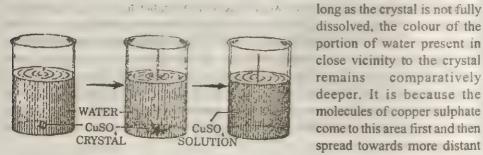


Fig. 3.1: Experiment on diffusion.

dissolved, the colour of the portion of water present in close vicinity to the crystal remains comparatively deeper. It is because the molecules of copper sulphate come to this area first and then spread towards more distant areas. When the crystal is fully dissolved, its molecules

become uniformly distributed throughout, and the whole water becomes equally coloured. This is an example of diffusion of a solid in a liquid medium.

- [2] If a drop of ink is dropped in a beaker containing water, the colour of the ink will gradually spread throughout the water and finally the whole water will be uniformly coloured (diffusion between two liquids).
- [3] Similarly, on adding some sugar (solid) or sugar solution (liquid) to water (liquid) taken in a container, the whole water will finally become equally sweet due to diffusion of sugar molecules in water.
- [4] When an odorous substance such as a gas like H,S or a material like camphor, petrol, naptha etc. (which is volatile and easily transformed into gaseous state) is exposed to air at one corner of a room, its odour spreads throughout the room (diffusion of gas in gas).
- [5] When sugar and salt are together added to water, their molecules diffuse simultaneously in water. Similarly, if two or more gases are expossed in a room, all the gases will simultaneously diffuse in the air of the room.

Factors affecting diffusion:

The rate or velocity of diffusion is influenced by the following factors:

- [1] Concentration gradient— It has already been stated that the chief driving force of diffusion is the difference in pressure (or diffusion pressure gradient) and that diffusion pressure in turn is dependent on concentration of the diffusible molecules. Obviously therefore, the velocity of diffusion is directly proportional to the concentration gradient. In case of gases, diffusion is dependent on the pressure gradient (i.e. difference of partial pressure of the gas) and in case of ions, the diffusion rate is dependent on the electrical gradient (i.e. potential difference).
- [2] Molecular size—Rate of diffusion is inversely proportional to the size and weight of the diffusible molecules, that is, bigger is the molecule, slower is the rate of its diffusion.
- [3] Temperature—Velocity of diffusion is directly proportional to the temperature because rise of temperature increases the kinetic energy of the molecules and hence the molecular motion.
- [4] Medium of diffusion: The rate of diffusion is influenced by the medium in which diffusion occurs and it is inversely proportional to the concentration of the particles or molecules of the medium. The more is the number of medium-molecules, the lower is the rate of diffusion and vice versa. This is caused by collision of the medium-molecules with the diffusing molecules, which interferes the movement of diffusing molecules. This is why a gas diffuses more rapidly through a vacuum than in air.
- [5] Density of the diffusing material: The rate of diffusion depends upon the density of the diffusing material and the former is inversely proportional to the square

root of the latter, i.e. $r \propto \frac{1}{\sqrt{d}}$, where r- rate of diffusion, and d = density of the diffusing material. This is known as **Graham's law of diffusion.**

[6] Distance— The greater is the distance between the regions of higher concentration and lower concentration, the more will be the time required for diffusion; that is diffusion rate is inversely proportional to the distance.

Pressure gradient: Concentration gradient (or Chemical gradient): Electrical (or Potential) gradient:

Pressure gradient is the difference of partial pressure of a gas across a cell membrane due to which the gas diffuses through the membrane from the region of higher pressure to the region of lower pressure. The rate of diffusion varies directly with the difference between the partial pressures on the two sides and varies inversely with the square root of the density of the gas.

Concentration gradient is the difference of concentration between two solutions present at the two sides of a cell membrane by means of which the molecules diffuse through the membrane from the region of higher concentration to that of lower concentration. The rate of diffusion varies directly with the difference of concentration between the two regions.

Electrical gradient is difference of electrical potential between te two sides of a cell membrane due to which the ions diffuse through the membrane from the side of higher potential to the side of lower potential. This electrical (or potential) gradient is caused by an uneven distribution of ions across the membrane.

Diffusion in biological systems:

In a living body, diffusion mainly occurs in a liquid medium because both the inside and the outside of the living cells are fluid in nature that are called intracellular fluid (ICF) and extracellular fluid (ECF) respectively. Diffusion in a biological system (living body) may be of two main types:

[1] A material entering into the ECF or ICF may directly diffuse through it; for example—the materials entering the blood spread in plasma; nutrients entering the cells diffuse throughout the cytoplasm etc.

[2] Diffusion may take place across a cell membrane for exchange of materials between ICF and ECF; for example—supply of nutrients from blood to the cells; expulsion of excretory materials from cells to blood etc. Since the process of transport of materials across a membrane by diffusion does not require expenditure of energy, it is called passive transport. It may occur in three ways as described below with examples—

(a) Diffusion in dissolved state through the lipid matrix: A few substances such as O₂, CO₂, alcohol, fatty acids etc. are soluble in lipid as well as in water. These may diffuse through a membrane after being dissolved in the lipid of the membrane. The primary factor that determines the rate of such diffusion is the solubility of a substance in the lipid matrix of the membrane.

(b) Carrier mediated diffusion: Some substances like sugars, amino acids etc. are very insoluble in lipid and yet can diffuse through the lipid matrix of a membrane

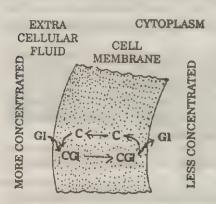


Fig. 3.2: Carrier (C) mediated facilitated diffusion of glucose (Gl).

with the aid of certain carriers present in the membrane. This process is known as carrier mediated diffusion or facilitated diffusion. For this, the carrier substance combines with the sugar or amino acid molecules at one side of the membrane. This combination is soluble in lipid so that it can diffuse to the other side of the membrane where the molecules carried (glucose or amino acid) are detached from the carrier. The carrier moves back to the former side of the membrane for picking up new sugar or amino acid molecules. Such carrier molecules are examples of the uniport. The chief determinant of this types of diffusion is

the amount of carrier available and the rapidity with which it can react (combine or detach) with the molecule to be carried.

(c) Diffusion through the membrane pores: Water and many of the dissolved ions diffuse across a membrane through the so called pores present in it. The pores are approximately 0.8 nm (8Å) in diameter. Naturally, only those particles having diameter equal to or less than this can pass through a membrane by this process. The diffusion of ions usually occurs through ion channels that are transmembrane proteins functioning as slective pores.

Physiological importance (or significance) of diffusion:

Various physiological functions (life processes) of plants and animals involving movement of materials from one place to another, are carried out by means of diffusion.

The chief functions served by diffusion in biological systems are the following—(i) transport of respiratory gases (O_2 and CO_2); (ii) absorption of some nutrients from intestine to blood in animals and absorption of some ions from the soil by the root hair of plants; (iii) exchange of materials between tissues and capillaries; for example, supply of nutrients from blood to the tissue cells, and drainage of waste matters and CO_2 from the tissue to blood; (iv) exchange of materials between RBC and plasma; (v) transpiration from leaves of plants and insensible perspitration from the skin of animals; (vi) admixture of enzymes and substrates in the alimentary canal for digestion or within cells for metabolism.

3.2. Osmosis

Definition: Osmosis is a physical phenomenon of net flow of solvent molecules from a solution of lower concentration to a solution of higher concentration through a semipermeable membrane which separates the two solutions.

or

Osmosis is the physical process of net diffusion of solvent molecules across a semipermeable membrane.

Different types of membranes :

Since osmosis is a diffusion through a semipermeable membrane, it is necessary to have an idea about the different types of membranes. The term membrane means a thin sheet or layer of plant or animal or artificial origin. On the basis of permeability, the membranes are divided into the following four types:

- [1] Permeable membrane— If a membrane allows free diffussion of both solvent and solute molecules, it is called permeable membrane, e.g, cellulose cell wall of plant cells.
- [2] Impermeable membrane— A membrane is called impermeable if it does not permit free diffusion of both solute and solvent molecules, e.g. heavily cutinised or suberised cell wall of plant cells or a sheet of rubber.
- [3] Semipermeable membrane— A membrane is called semipermeable if it allows only the solvent molecules and not the solute molecules to pass (diffuse) freely through it, e.g. parchment paper, cellophane paper, fish bladder etc.
- [4] Differentially or selectively permeable membrane— Such membranes allow free passage (or diffusion) of solvent molecules and also of some selected solute molecules or ions through them, e.g. plasmalemma and the membranes of the cell organelles.

Explanation or Mechanism of Osmosis:

When two solutions of different concentrations (or a solution and the pure solvent) are separated by a semipermeable membrane, there occurs a net flow of solvent from the less concentrated solution (or pure solvent) to the more concentrated one. In fact, the solvent (water) molecules move in both directions across the semipermable membrane, but since the number of solvent molecules moving from the dilute to the concentrated side is much greater than that in the reverse direction, there is a net flow of solvent from the dilute to the concentrated side. Fig 3.3 shows the mechanism of osmosis when a sugar solution separated from water by a semipermeable membrane.

Osmosis is a special type of diffusion process in which the solvent molecules pass across a semipermeable membrane from a region having greater number of solvent

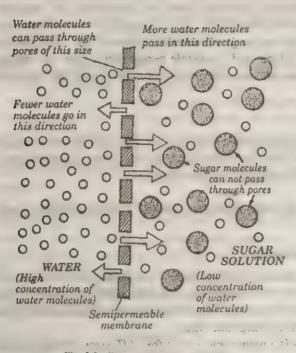


Fig. 3.3: Diagrammatic representation of the mechanism of osmosis

molecules (i.e. the dilute side) to the region having smaller number of solvent molecules (i.e. the concentrated side). Thus, osmosis can be considered as diffusion of solvent molecules across a semipermeable membrane.

The mechanism of osmosis may be explained on the basis of binding between solute and solvent molecules in a solution. The higher is the concentration (i.e. number of solute molecules) of a solution, the more will be the number of solvent molecules bound by the solute, thereby lowering the number of free solvent particles available for random motion. Thus, the less is the concentration of a solution, the more will be the

random motion of the free solvent molecules in it. For this reason, larger number of free solvent molecules pass from dilute to concentrated solution than in the reverse direction during osmosis.

With the progress of osmosis, the concentration gradient between the two solutions is gradually diminished and the hydrostatic pressure on the concentrated side gradually increases due to accumulation of solvent in it. Osmosis continues until an equilibrium is reached when the two solutions attain same concentration (i.e. the gradient of concentration is abolished) or the rise of hydrostatic pressure on the concentrated side becomes high enough to prevent further entry of solvent into this compartment.

Osmosis in Biological System:

In biological systems (i.e. living cells), osmosis occurs between the fluids present inside and outside the cells, separated by the plasmalemma. The fluid within the cells or the protoplasm is called intracellular fluid (ICF) and that present outside the cell is called extracellular fluid (ECF). The plasmalemma is considered as a semipermeable membrane, it permits water but not many solutes including proteins to pass freely (i.e. diffuse) through it. But in true sense, the plasmalemma is not a perfectly semipermeable membrane because a few solutes may as well diffuse through it. For this reason, now a days, the plasmalemma is designated as a selectively or differentially permeable membrane. However, osmosis takes place through plasma membrane whenever the ICF and ECF differ in concentration. Thus, osmosis in biological field means diffusion of water across the plasma membrane in response to a concentration gradient.

 Types of osmosis: In living cells, depending upon the direction of flow of water, osmosis may be of two types—endosmosis and exosmosis.

The entry of water into a cell from its surrounding by osmosis is called **endosmosis** which occurs when the ICF (protoplasm) become more concentrated than the ECF. Conversely, when the ICF becomes less concentrated than the ECF, water flows out of the cell (i.e. ICF to ECF); this is known as **exosmosis**. Endosmosis and exosmosis in animal cells result in a swelling and shrinkage (crenation) of the cells respectively. **Plant** cells are protected from such osmotic deformities due to the presence of a rigid cell wall. In plant cells, a prolonged exosmosis may lead to shrinkage of protoplasm which retreats from the cell wall and accumulates centrally; this is known as **plasmolysis**. The protoplasm of a plasmolysed cell may regain its original form by endosmosis; this phenomenon is called **deplasmolysis**.

• Plasmolysis: Incipient plasmolysis: Deplasmolysis:

These three phenomena are seen in plant cells due to osmotic effects on them. When a living plant cell is placed in a hypertonic solution (i.e. a solution more concentrated than the cell sap) of sugar or salt, water from the cell sap diffuses out through the cell membrane due to exosmosis. The loss of water from the cell causes contraction or shrinkage of the protoplasm. As the cell wall is rigid and less elastic, it cannot keep pace with the shrikage of protoplasm; hence the cell membrane is pulled away from the cell wall. Further loss of water from the cell contents causes more contraction of protoplasm, which finally recedes completely from the cell wall and assumes a spherical shape. At this stage, the cell is said to be in plasmolysed condition, and the phenomenon is called plasmolysis. Plasmolysis can be defined as the phenomenon of contraction of protoplasm of a living plant cell due to exosmosis. In

the plasmolysed cell, the space between the cell wall and the contracted protoplasm is occupied by the external hypertonic solution plus water, which has diffused out of the protoplasm.

The initial stage of plasmolysis, when the cell wall has reached its limit of contraction but the protoplasm has not yet receded from the cell wall, is called incipient plasmolysis. Thus, incipient plasmolysis can be defined as the stage of plasmolysis at which the first

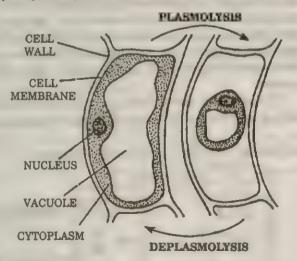


Fig. 3.4: Plasmolysis and deplasmolysis.

sign of shrinkage of protoplasm is detectable.

If a plasmolysed cell is placed in hypotonic solution or distilled water, endosmosis occurs and the cell regains its turgidity and original shape and size. This process is called **deplasmolysis**. Thus, deplasmolysis can be defined as reversal of plasmolysis.

•Isotonic, Hypertonic and Hypotonic solutions:

A solution which exerts no osmotic effect on the cells (i.e. the cells neither take in nor give out water when suspended in this solution) is known as isotonic solution. For

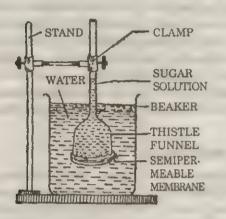


Fig. 3.5: Experiment on osmosis

example, 0.9 gm% NaCl solution in water is isotonic for mammalian cells: hence this solution is also called mammalian normal (or isotonic) saline. For amphibian cells, 0.65 gm% NaCl solution in water is isotonic. A solution which causes exosmosis in a cell (i.e. draws out water from it) when the cell is suspended in the solution, is called hypertonic solution. NaCl solutions above 0.9 gm% and 0.65% are hypertonic to mammalian and amphibian respectively. A solution is called hypotonic. if it causes endosmosis (or inflow of water) in the cells when these are kept in that solution. NaCI solutions

concentrations lower than 0.9 gm% ans 0.65 gm% are called hypotonic to mammalian and amphibian cells respectively.

Experiments and examples of Osmosis:

[1] The wide mouth of a thistle funnel is tied with a semipermeable membrane e.g. parchment paper or fish bladder. The funnel is filled with a strong sugar solution through the opening of its narrow tube and the level of the solution in the tube is marked. Then the wide end of the funnel is immersed in water contained in a beaker so that the funnel does not touch the bottom of the beaker and the tube of the funnel is clamped to a stand. After some time, it will be seen that the level of the sugar solution in the tube of the funnel has raised from the initial mark. This clearly shows that the water (solvent) from beaker has entered into the concentrated sugar solution through the membrane by osmosis:

[2] When some animal cells (e.g. red blood cells of man or toad) are placed in an isotonic solution (e.g. 0.9% or 0.65% saline respectively), the cells remain unchanged

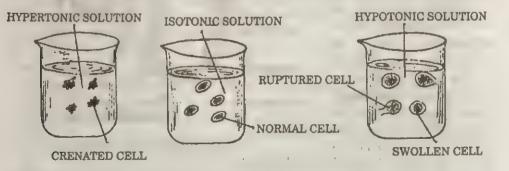


Fig. 3.6: Effect of osmosis on living animal cells.

and retain their shape and size indicating that no osmosis has taken place. But when the cells are placed in a hypertonic (i.e. more concentrated) solution, they become

shrunken and crenated indicating exosmosis. Conversely, when placed in a hypotonic or dilute solution or pure water, the cells swell and may even burst due to endosmosis.

[3] If a fresh water fish is kept in marine water (hypertonic), it will soon die because of cellular dehydration resulting from exosmosis. A marine fish, if transferred to fresh water, will also be unable to survive for a long time. This is because of endosmosis and excess water accumulation within the cells, finally leading to their rupture.

Cell to cell osmosis and its experiment:

Osmosis between the adjacent cells of plants and animals is called cell to cell osmosis. By virtue of this, the osmotic effects are transferred from one cell to the next and so on.

For example, if a cell draws water (solvent) from the surrounding by endosmosis, its protoplasm becomes dilute in comparison to that of the next cell. So the latter draws water from the former and in this way the water is passed from cell to cell. This can be shown by the following experiment:

A large potato is peeled and slices are cut off from all sides to make a square block of it. Then the central portion of it is scooped off so that it looks like a cup. A strong sugar solution is put into the hollow cavity to fill it partly and the level is marked

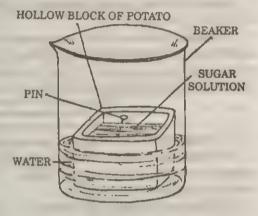


Fig. 3.7: Experiment on cell to cell osmosis.

by inserting a pin. The potato block is finally placed in a beaker containing water taking care that it is not totally submerged under water. After some time, it will be seen that the level of sugar solution in the potato cup has risen up from the initial mark. This shows that the solution has drawn water from the beaker across the series of potato cells by a process of cell osmosis.

Physiological importance (or significance) of osmosis:

A. In plants:

- [1] Absorption of water from soil by the root hairs of plants occur due to osmosis.
- [2] The water absorbed by the root hairs is transferred to the cortical cells and then through the xylem vessels to different parts of the plant by virtue of cell to cell osmosis.
- [3] Endosmosis in plant cells develop turgor pressure which helps in several functions, such as—
 - (i) Control of stomatal opening and closing.
 - (ii) Growth of meristematic tissue.
- (iii) Various types of movements, e,g, seismonasty in *Mumosa*, dehiscence of sporangium and fruits, opening of flowers etc.
- (iv)Rigidity and mechanical support to soft plant organs, e.g. the leaves are held in position and the seedling as well as the herbs stand erect due to the turgor pressure in their cells.

B. In animals:

- [1] Water content of animal cells is maintained by osmosis between ICF and ECF.
- [2] Osmosis helps in various functions involving exchange of water between blood

and tissues e.g. absorption of water from the intestine or kidneys, glomerular ultrafiltration, maintenance of blood volume etc.

[3] Osmotic pressure of blood regulates the release of ADH.

Osmotic Pressure (OP):

Definition: Osmotic pressure of a solution is the hydrostatic pressure generated due to osmosis between that solution and pure water. Osmotic pressure of a solution may also be defined as (and also measured by) the pressure that must be applied on the solution to prevent the inflow of water from pure water to the solution when they are separated by a semipermeable membrane.

Factors affecting osmotic pressure: Osmotic pressure of a solution depends on the following factors:

[1] Concentration— Osmotic pressure (OP) of a solution is due to the solute molecules in it, so osmotic pressure is directly proportional to the molar concentration of the solute in it (*i.e.* number of gm. moles of the solute per litre of the solution). Equimolar solutions of non-ionised solutes exert the same osmotic pressure.

:. OP a concentration solution.

- [2] Temperature— OP is directly proportional to the absolute temperature.
- [3] Ionisation of solute— An ionised solute exerts more osmotic pressure than an equimolar solution of non-ionisable solutes. This is because each ion exerts osmotic pressure as a separate solute particle.
- [4] Molecular weight of the solute— Osmotic pressure is inversely proportional to the molecular weight (MW) of the solute. A solute having low molecular weight (e.g. glucose) exerts more osmotic pressure than one having a higher molecular weight (e.g. glycogen).

Turgor pressure (TP):

If a living plant cell is placed in water, it absorbs water and swells up due to endosmosis. As a result of entry of water into the cell sap, a pressure is developed in the protoplasm which presses the cell membrane against the cell wall. This pressure is called turgor pressure and the cell is said to be in a turgid state. Thus, turgor pressure can be defined as the hydrostatic pressure which presses the protoplasm against the cell wall. Turgor pressure is due to entry of water into the cell sap, i.e. decrease in concentration of the cell sap. So, with the decrease in concentration of the cell sap, the turgor pressure increases and vice verse. Thus turgor pressure is inversely proportional to the concentration of the cell sap.

Wall pressure (WP):

Plant cells possess a non-elastic and rigid cell wall, which exerts an opposite and equal pressure to counterbalance the turgor pressure. This pressure exerted by the cell wall is called wall pressure. Thus, wall pressure can be defined as the pressure exerted by the cell wall against the turgor pressure. Due to this wall pressure, unlike the animal cells, the plant cells usually do not burst when kept in water for a long time and they become turgid.

Diffusion pressure deficit (DPD) or Suction pressure (SP):

The terms diffusion pressure deficit (DPD) and suction pressure were introduced by Meyer (1938). Like the gases and solutes, liquids also have DP. The DP is maximum in pure water (or any other pure solvent). When a solute is added to pure water (or solvent) the DP of the solvent in the resulting solution is lowered with respect to the pure solvent. This is because the free energy of the solvent is decreased in presence of the solute. Thus, the DP of water or a solvent in a solution is always lower than that of the pure solvent.

The term diffusion pressure deficit (DPD) of a solution refers to the amount by which the DP of the solvent in the solution is lower than the DP of its pure solvent at the same temperature and pressure.

Thus, DPD of a solution = DP of pure solvent - DP of solvent in the solution.

The DP of the solvent in a solution is inversely proportional to the concentration of the solution (i.e. number of solute particles per unit volume of the solution). That means, the higher is the concentration of a solution, the lower will be the DP of its solvent and as a result, greater will be the DPD of the solution. Thus, DPD of a solution is directly proportional to its concentration, i.e. DPD of a solution increases with increase in concentration of the solute particles in the solution.

In a cell, higher is the DPD of the cytoplasm, more will be the entry of water into the cell (or endosmosis) and vice versa. For this reason, DPD of a cell cytoplasm is also called **suction pressure** or **suction force** which can be *defined as the force per unit area by which water enters into a cell.* The term DPD is frequently used to explain the mechanism of osmosis because during osmosis, the solvent molecules flow from a solution having lower DPD to a solution having higher DPD. It should be noted that the DPD of a solution is of **positive** value.

Relationship between Concentration and DP, OP, DPD:

- 1. DP of a material \(\alpha \) Concentration of diffusing molecules or ions.
- 2. OP of a solution α Concentration of the solution.
- 3. DP of the solvent in a solution α Concentration of the solution.
- 4, DPD of a solution α Concentration of the solution.
- 5. OP a DPD

Interrelationship of OP, TP (WP) and DPD (SP):

When a plant cell is placed in pure water, water enters into the cell and as a result, the TP of the cell is increased with a simultaneous increase in WP. The TP and WP are equal in magnitude but opposite in direction. Therefore, the actual force by which water enters into the cell, i.e. the DPD (or SP) equals to OP – WP. As the WP and TP are equal, DPD (SP) = OP-TP.

In case of a flaccid cell where the TP - O, the DPD - OP · O, i.e DPD - OP. Under such conditions, when DPD equals to OP, the rate of entry of water into the cell is maximal. On the other hand, in case of a fully turgid cell, the TP · OP. : DPD = OP-

TP = 0. Under such conditions, when DPD becomes zero, the entry of water into the cell (or endosmosis) is stopped.

Concept of Gibb's free energy, chemical potential and water potential:

The principle of the thermodynamics can be applied to explain the osmotic relations of the cells. At a temperature above absolute zero (or -273°C), the molecules of a substance possess certain amount of kinetic energy which is called free energy or Gibbs free energy.

The free energy can be defined as the sum of energy of a system capable of doing work. The free energy is the thermodynamic parameter that determines the direction of a physical or chemical change. The free energy per mole (gram molecular weight) of a chemical substance is called chemical potential. Diffusion of a substance depends on its chemical potential and it (diffusion) occurs in energetically down-hill direction (i.e. from higher to lower chemical potential). The chemical potential of water is expressed as water potential. The term water potential was introduced by Stayler and Tayler (1960) to express the free energy of water in a system (solution).

The water potential of a solution is defined as the difference between the free energy of water molecules in pure water and the free energy of water in the solution. The water potential is denoted by the Greek letter Ψ (psi) or Ψ w and is measured in bars (bar is an unit of pressure; 1 bar = 0.987 atm. or 10^6 dynes/cm²). The water potential of pure water is zero and it is lowered by adding solute molecules. This occurs because the free energy of water is decreased by the presence of solute molecules or ions that collide with the water molecules. Therefore, the water potential of a solution is always less than zero, hence it is negative value. Water potential of a solution is dependent on the concentration of the solution. With an increase in concentration of a solution, the water potential becomes more negative (i.e. decreased) and vice versa. Thus, water potential is inversely proportional to the concentration of a solution.

Now a days the term water potential is often used instead of DPD to explain the mechanism of diffusion of water and osmosis. Movement of water molecules take place in an energetically down-hill direction, i.e. from a region of higher water potential (i.e. less negative) to a region of lower water potential (i.e. more negative). It should be noted that the water potential of protoplasm of a cell is equal to the DPD or SP, but opposite in sign; the DPD is a positive value whereas water potential is a negative value. In a normal cell, the water potential (\Ps) is mathematically expressed as the sum of osmotic potential or solute potential (\Ps) and pressure potential (\Pp).

Therefore,
$$\Psi w = \Psi_S + \Psi_P$$
.

The solute potential or osmotic potential refers to the amount by which water potential is reduced due to the presence of solutes in a solution. It is directly proportional to the concentration of the solution, i.e. it increases with increase in solute concentration and vice versa.

The pressure potential refers to turgor pressure (TP) and is directly proportional to the amount of water present in the cell sap of the vacuole. It is zero in non-vacuolated cells. The solute potential is a negative value whereas the pressure potential is a positive value.

• Difference between Diffusion and Osmosis •

Diffusion	Osmosis
[1] It occurs in a gaseous or a liquid	[1] It occurs only in a liquid medium.
medium.	
[2] For diffusion, presence of a membrane	[2] Presence of a membrane is
is not essential; it may occur both in	essential for osmosis.
absence or presence of a membrane.	
[3] In diffusion, both the solute and solvent	[3] In osmosis, only the solvent
molecules migrate.	molecules migrate.
[4] It may take place between solutions	[4] It takes place between solutions
having different solvents.	having the same solvent.

3.3. Absorption

Although the covering of the living cells separate the protoplasm or intracellular fluid (ICF) from the extracellular fluid (ECF), there occurs a continuous exchange of materials between these two fluids. Such exchange is very important for maintaining various physiological functions. By virtue of this exchange meachanism, various materials are taken into the cells from their surroundings while some others are given out by the cells to the ECF. Of these, the former process is known as absorption.

• Definition of Absorption: The process of entry of materials into the cells from their surroundings is called absorption.

• Types of Absorption:

The process of absorption by the cells may be of two types—passive and active. The main features of these two types of absorption mechanisms are discussed below in brief.

[1] Passive absorption: The process by which the materials present in ECF in higher concentration than their concentration in protoplasm are absorbed by the cells without expenditure of energy is called passive absorption.

It is carried out by diffusion or osmosis. Both these processes have been described earlier. Various materials like gases, water and some solutes (electrolytes or ions as well as non-electrolytes) are absorbed by living cells passively, in different ways. Oxygen is absorbed by cells (for cellular respiration) by diffusion through the lipid matrix of cell membrane. It occurs due to the gradient of pO₂ (partial pressure of O₂) between the two sides of the cell membrane (i.e. high pO₂ outside the cell and low pO₂ inside the cell). Water is absorbed by cells due to endosmosis. Diffusible ions (electrolytes) are absorbed passively through ion channels present in the cell membrane due to electrical gradient. Non-electrolytes like sugars are absorbed by carrier mediated facilitated diffusion due to concentration gradient. Red blood cells absorb C1 and glucose passively by the above mentioned mechanism. Passive absorption depends on the permeability of the cell membrane. The permeability of a membrane for a given substance can be defined as the net rate of diffusion of the substance through each unit area of the membrane for a given concentration difference. Permeability of cell membrane is dependent on the following factors:—

(i) Lipid solubility— Lipid soluble materials can easily diffuse through the cell membrane. Obviously therefore, the permeability of a cell membrane for a substance is directly proportional to the lipid solubility of the substance, *i.e.* the more is the lipid solublity of a substance, the more will be the cell membrane permeable to it.

(ii) Porosity and thickness of the membrane— Larger is the number and size of the pores in a cell membrane (i.e. porosity of the membrane), higher is its permeability. In other words, permeability of a membrane is directly proportional to its porosity. On the other hand, permeability is inversely proportional to the thickness of the membrane.

(iii) Size of the molecules or ions—Bigger molecules or ions are allowed to diffuse through a membrane less readily. So, the permeability of a membrane to a substance is

inversely proportional to the molecular size (weight) and ionic volume.

- (iv) Concentration and electrical gradient— It is the chief driving force for diffusion. So, the more is the concentration of a substances in the ECF than in ICF, the greater will be the rate of its absorption by the cell. Absorption of ions through the membrane pores (channels) depend on both concentration gradient as well as electrical gradient.
- (v) Availability of carrier—The permeability of the membrane for those substances which are absorbed by the process of carrier mediated facilitated diffusion depends on availability of the carrier in the cell membrane. The more is the number of carrier molecules present in the membrane and their ability to react with (i e combine with and detach from) the substance to be absorbed, the greater will be the permeability of the membrane for the substance.
- (vi) Temperature—Rise of temparature increases the molecular motion and thereby the rate of diffusion and permeability. However, a very high tempetrature may decrease permeability.
- (vii) Other factors— In addition to the above, certain other factors also influence the permeability of cell membrane as follows—
- (a) Presence of excess Ca2+ in the ECF reduces the permeability and a decrease of extracellular Ca2+ concentration increases the permeability.
- (b) Some hormones may influence the permeability of certain cells; for example, insulin increases the permeability of various cells to glucose and amino acids, ADH renders certain cells of renal tubules permeable to water, etc.
 - (c) lonising radiation, Injury and aging may also increase the cell permeability.
- [2] Active absorption: The process of absorption which is driven by metabolic energy instead of a concentration gradient and requires the presence of a suitable carrier is called active absorption.

This process generally takes place against a gradient of concentration *i.e.* from lower to higher concentration. Substances which are present in the ECF in minute quantities but are required within the cells in large quantities are absorbed by active

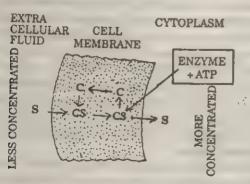


Fig. 3.8: Process of active absorption [C] carrier, S - substance to be absorbed]

process at the cost of energy expenditure. The mechanism of active absorption is given below.

There are certain carriers in the cell membrane. The carriers are proteins but unlike the ion channels, the carrier proteins do not have pores. They can specifically bind with certain substances (i.e. they have special affinity for these substances). The substances to be absorbed (S) combines with the carrier (C) at the outer surface of the cell membrane to form a complex (CS) which diffuses

through the membrane to the inner surface. At the inside surface of the membrane, S separates from C and is released within the cell. The detachment of C and S requires an enzyme and ATP (source of energy) that are present in the cytoplasm of the cell C then moves back to the outer surface to pick up more S. Thus, it is apparent that the mechanism of active absorption is very similar to that of facilitated diffusion, except that the former requires an enzyme, and expenditure of energy for transport against a concentration gradient. It has been observed that anoxia or administration of metabolic inhibitors which interfere with cellular oxidation and production of ATP, impairs active absorption by the cells. This clearly indicates the essential requirement of ATP (metabolic energy) for active absorption.

Only some solutes (both non-electrolytes and ions) are absorbed by certain cells activity. Non-electrolytes like sugars, amino acids etc. are absorbed by intestinal and renal tubular cells by active transport. It is very important because it helps to absorb these materials almost entirely from the intestinal and tubular lumen even though the concentration of these materials in the lumen falls much below that within the cells in the course of absorption. Flectrolytes (ions) are actively absorbed by certain cells with the help of ion pumps. For example, thyroid cells actively trap iodide from blood for synthesis of thyroid homones, even though the concentration of iodide in blood is much lower than that within the thyroid cells. Na. and K. are actively absorbed by renal tubular cells to return these ions to blood from the filtrate.

● Difference between passive and active absorption or Difference between Passive transport (diffusion) and active transport ●

Passive absorption (or Passive Active absorption (or Active transport or Diffusion) transport) [1] It does not require energy [1] It requires expenditure of energy, hence it is depudent on cellular oxidation expenditure; hence it is independent of cellular oxidation and is not inhibited by and is inhibited by anoxia. anoxia. [2] Carriers are essentially required [2] It may occur with or without the for this process. help of carriers. [3] Enzymes are essential for this [3] It does not require enzymes. process. [4] It is not driven by a concentration [4] It is driven by a concentration (or (or electrical) gradient and generally electrical) gradient and occurs only in favour of it.

• Difference between Osmosis and Absorption.

Osmosis	Absorption
1. It is the process of passage of water through a semipermeable membrane from a solution of lower concentration to a solution of higher concentration. 2. In this, only water molecules pass through the membrane. 3. It is a passive process. 4. It does not require carrier.	1. It is the process of entry of materials into a cell. 2. In this, both water and solutes can pass through cell membrane. 3. It may be passive or active process, 4. It may or may not require carrier.

3.4. Osmoregulation in freshwater and marine animals.

Maintenance of osmotic pressure, (i.e. solute concentration or osmolarity) of body fluids (e.g. blood) in an animal is known as osmoregulation. This is very important for maintaining the volume of body fluids as well as the shape and size of cells. Osmoregulation means regulation of solute movements, and hence water movement, which follows solutes by osmosis. It is accomplished by regulating the intake and excretion of salts and water by an animal. Depending on their osmoregulatory ability, animals may be of two broad types osmoconformers and osmoregulators.

Osmoconformers are animals which can tolerate a wide range of cellular osmotic environment. They do not actively control the osmotic condition of their body fluids, rather they change the osmolarity of body fluids according to the osmolarity of the surrounding medium in which they live. All marine invertebrates and some fresh water invertebrates are osmoconformers. Hagfish is the only vertebrate belonging to this group.

Osmoregulators are animals that maintain an internal osmolarity, different from the surrounding medium in which they live. Most vertebrates and some aquatic invertebrates belong to this group. Osmoregulators living in a hypotonic medium, have to eliminate the excess water gained from the medium, while those living in a hypertonic medium, must continuously take in water to compensate for water loss. Therefore, such animals have to spend energy for manipulating solute concentrations in their body fluids to move water in or out and maintain osmotic gradient.

Osmoregulation in fresh water animals:

The body fluids of the freshwater animals are generally hypertonic to their surrounding medium. So, they have to face two kinds of osmoregulatory problems—they continuously gain water from the surrounding medium and lose body salts to the surrounding medium. Fesh water animals tackle this problem (gain of water and loss of body salts) by several means.

Protozoa like Amoeba and Paramoecium living in fresh water, have contractile vacuoles that pump out excess water. Fresh water vertebrates including fishes do not drink water to reduce the need to expel excess water. However, the gill membrane absorbs water passively from the surrounding medium. Their kidneys retain salt in the body and excrete a large volume of very dilute urine to eliminate excess water. In these animals, water upake and salt loss are minimised by a specialised body covering such as scales over the body of fishes and crocodiles and subcutaneous fat in the scaleless fishes. Moreover, fresh water fishes have remarkable ability to take up salts actively from the surrounding hypotonic environment. For this, specialised cells called ionocytes or chloride cells are present in the gill membrane, which can absorb Na⁺ and Cl from the surrounding medium.

Osmoregulation in marine animals:

As the sea water has a high salinity and osmoregularity, the osmoregulatory problems in marine animals are opposite those in fresh water animals. The body fluids of marine bony fishes are hypotonic to sea water, and thus, they tend to lose water from the body through permeable surfaces like gill membranes, oral and anal membranes etc. To compensate for water loss, they drink sea water, which leads to gain of both water and salts. The excess salts are eliminated through gills and feces. The ionocytes (or

chloride cells) of the gill membrane of marine bony fishes help to pump out monovalent ions like Na' K* and Cl from the body fluid to sea water. Divalent cations like Mg^{2*} and So₄²⁺ are excreted through the feces.

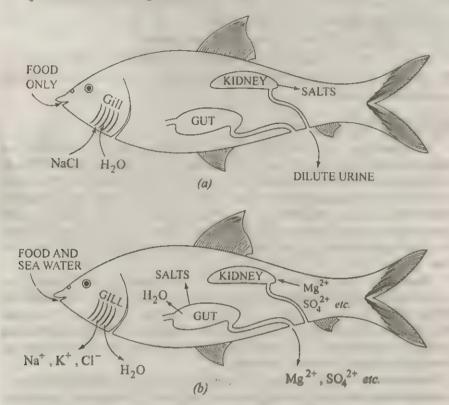


Fig. 3.9: Osmoregulation (water and solute balance) in fresh water (a) and marine (b) bony fish

Fishes like hilsa, salmon etc which migrate between sea water and fresh water are adapted to both the environments and have dual osmoregulatory mechanisms. When in sea water, they drink the sea water and elimenate the excess salts through gill membrane, to keep the body fluid hypotonic to sea water. Conversely, when in fresh water, they do not drink, but absorb salt through gills and excrete dilute urine to keep the body fluid hypertonic to the surrounding medium. Some hormones play a key role in this switching over process.

In elasmobranch fishes like sharks living in sea water, the osmolarity of body fluid is raised by accumulating certain organic substances called **osmolytes**, e.g. urea and trimethylamine oxide (TMAO). This prevents loss of water from their body fluids. The body fluid of such animals is slightly hyperosomotic to sea warer due to retention of osmolytes but hypotonic to sea water as they maintain much lower concentration of inorganic ions in the body fluid.

3.5. Matters to Recollect

Migration of particles fom higher to lower concentration is called diffusion.

Osmosis is a passive process of diffusion of solvent molecules across a semipermeable membrane.

- In plant cells, retraction of protoplasm due to exosmosis is called **plasmolysis** and its reverse phenomenon is called **deplasmolysis**.
- Osmotic pressure of a solution is directly proportional to its concentration.
- Passive absorption is a diffusion process.
- Energy driven absorption is called active absorption.
- Animals having osmoregulatory mechanism are called osmoregulators.
- Animals which do not have osmoregulatory mechanism are called osmoconformers.

3.6. Summary

Difussion: It is a process of spreading of molecules or ions of a substance from higher to lower concentration due to their inherent random motion. Rate of diffusion is directly proportional to the gradient of concentration (*i.e.* diffusion pressure) and temperature, and inversely proportional to the molecular weight of the material. Diffusion can occur across the biological membranes through the pores or by dissolving in the lipid matrix or with the help of membrane bound carriers. Diffusion plays an important role in respiratory gaseous exchange, absorption of materials etc.

Osmosis— When two solutions of different concentrations (or a solution and the pure solvent) are separated by a semipermeable membrane, the solvent molecules diffuse from the dilute solution to the concentrated one. This is called osmosis. Entry and exit of water to and from a cell by this process are called endosmosis and exosmosis respectively. Osmosis helps in absorption of water by the cells and development of turgor pressure in them.

Absorption—Entry of a material from ECF to the cell is called absorption. It may occur passively or actively. Passive absorption is driven by gradient of concentration and occurs in favour of it, requiring no energy expenditure. Active absorption is driven by energy and may even occur against a gradient of concentration. Gases and water are absorbed passively by diffusion and osmosis respectively. Non-electrolytes, e.g. sugars may be absorbed by facilitated diffusion or active transport. Electrolytes (ions) are absorbed passively through ion channels or actively through ion pumps.

Osmoregulation— Inspite of the variation in the water environment in which they live, both fresh water fishes and marine fishes can maintain a constant osmotic pressure of their body fluids, which is different from that of the surrounding water. This is called osmoregulation. For this, the fresh water and marine fishes adopt different mechanisms.

3.7. Answer to special questions:

- [1] What is selective permeability? (J.E.E. 1988)

 Ans. Selective permeability is a property of the cell membrane by virtue of which it permits water and some selected particles (solutes) to diffuse throught it.
- [2] What is semipermeable membrane and how does it differ from a selectively permeable membrane? (J.E.E. 1983)

 Ans. A semipermeable membrane permits diffusion of solvent molecules only,

but not the solutes, through it whereas a selectively permeable membrane permits the solvent and some but not all solutes to diffuse through it.

[3] What is active transport?

(J.E.E. 1989)

Ans. Active transport is an energy driven process of transport across the cell membrane with the help of certain carrier molecule present in the membrane. It is independent of gradient of concentration or electrical potential between the two sides of the membrane and it may occur even against the gradient.

[4] Define diffusion, osmosis and facilitated diffusion. (J.E.E. 1991)

Ans. Diffusion— Diffusion is a physical process in which molecules or ions of a matter, by virtue of their inherent random motion, migrate from a region of higher concentration to a region of lower concentration until equality of concentration is reached.

Osmosis—Osmosis is a physical process of net flow of solvent molecules through a semipermeable membrane from the solution of lower concentration to the solution of higher concentration when the two solutions are separated by the membrane. Osmosis may also be defined as the physical process of net diffusion of solvent molecules across a semipermeable membrane.

Facilitated diffusion— The process of diffusion of lipid-insoluble materials through the lipid martix of biological membranes with the aid of certain carriers is called facilitated diffusion or carrier mediated diffusion.

[5] What do you mean by isotonic, hypotonic and hypertonic solution?

(J.E.E. 1982)

Ans. A solution is called **isotonic** which exerts no osmotic effect on a living cell, *i.e.* when the cell is placed in such a solution, there occurs neither exosmosis nor endosmosis. A solution is called **hypotonic** if it causes endosmosis or inflow of water in the cell when the cell is suspended in the solution. Conversely, when the cell is placed in a solution and there occurs exosmosis, the solution is said to be **hypertonic**.

[6] What are exosmosis and endosmosis? (J.E.E. 1991)

Ans. Exosmosis means flow of water from the interior of a cell to the exterior

through the plasma membrane by the process of osmosis. It occurs when the extracelluar fluid (i.e. the fluid which bathes the cell) is more concentrated (or hypertonic) than the protoplasm. Conversely, endosmosis means entry of water into a cell from its surrounding through the plasma membrane by the process of osmosis. It occurs when the protoplasm is more concentrated than the surrounding fluid.

- [7] What happems to a living plant cell when it is placed in (i) a hypertonic solution and (ii) a hypotonic solution? (J.E.E. 1992)
 - Ans. (i) When a plant cell is placed in a hypertonic solution, there occurs exosmosis and shrinkage of protoplasm, as a result of which the protoplasm retreats from the cell wall leading to plasmolysis.
 - (ii) When a plant cell is placed in hypotonic solution, there occurs endosmosis and the cell becomes turgid.
- [8] Why meat or fish sprinkled with salt remains free from moulds and bacteria for a long time? (J.E.E. 1992)

 Ans. When meat or fish is sprinkled with salt, the cells of meat or fish become

dehydrated due to exosmosis caused by high salinity on their surface. This leads to high ionic concentration within the cells, which does not favour the growth of moulds and bacteria.

[9] What will happen if RBC of toad is placed in isotonic, hypertonic and hypotonic solutions? (J.E.E. 1986)

Ans. If RBC of toad is placed in isotonic solution, nothing will happen and the RBC will remain normal. If placed in hypertonic solution, the RBC will become shrunken and crenated due to exosmosis. If placed in hypotonic solution, the RBC will become swollen and turgid due to endosmosis.

[10] What will happen to a marine fish if it is placed in fresh water?

(J.E.E. 1986)

Ans. If a marine fish is placed in fresh water, it will not survive for a long time because of endosmosis and accumulation of excess water within the cells finally leading to their rupture. This happens because fresh water is hypotonic to the body fluid of the marine fish.

[11] Explain what will happen if a fresh water fish is kept in sea water?

(J.E.E. 1981)

Ans. Sea water is hypertonic to the body fluid of a fresh water fish. So, if a fresh water fish is kept in sea water, the fish will suffer from dehydration because it will lose water by exosmosis. As a result of prolonged dehydration, the fish will ultimately die.

[12] (a) What is cell osmosis?

(J.E.E. 1994)

Ans. Cell osmosis means passage of water through the cell membrane, *i.e.* exchange of water between a cell and its aquatic surrounding. By this process, water is taken in and expelled out of the cell.

[13] What is passive absorption of particles?

(J.E.E. 1987)

Ans. Passive absorption is a process of absorption or inward movement of particles due to diffusion or osmosis without expenditure of energy. It is driven by a gradient or concentration or pressure or electrical potential.

[14] Explain the following— (i) pressure gradient, (ii) concentration gradient, (iii) electrical gradient. (J.E.E. 1987)

Ans. (1) Pressure gradient is the difference of partial pressure of a gas between the two sides of a cell membrane due to which the gas diffuses through the membrane from the region of higher pressure to the region of lower pressure. The rate of diffusion is directly proportional to the pressure gradient.

(ii) Concentration gradient means the difference of concentration between the intracellular fluid and the extracellular fluid due to which the molecules diffuse from the region of higher concentration to that of lower concentration through the cell membrane. The rate of diffusion is directly proportional to the concentration gradient.

(iii) Electrical gradient is the difference of electrical potential across a cell membrane due to which the ions diffuse through the membrane from the side of

higher potential to the side of lower potential.

[15] When solution A, having osmotic pressure of 10 atmosphere, is separated from solution B, having osmotic pressure of 7 atmosphere, to which direction will the solvent molecules flow? Give reason. (J.E.E. 1991)

Ans. According to the principle of osmosis, solvent molecules will flow from

solution B to solution A because the former is less concentrated than the latter, *i.e.* the former contains relatively higher number of solvent molecules than that in the latter.

[16] How a herb or seedling stands erect on the soil? (J.E.E. 1980)

Ans. Althrough the herbs or seedlings do not have well developed mechanical tissue for their support, they stand erect by virtue of turgidity of their cells caused by water absorption. The root hairs spontaneously absorb water from the soil and pass it to all the cells by cell to cell osmosis. As a result of this, the cells of the herb or seedlingg become turgid and tightly packed which gives mechanical support to the plant for standing erect.

[17] The cytoplasm of a cell contains water and sugar in the ratio 50: 50. If it is placed in two solutions having water and sugar ratio of (i) 80: 20 and (ii) 20: 80 respectively, what physical change will be observed in the cell and why?

(Tripura H.S. 1982)

Ans. The first solution having water and sugar ratio of 80. 20 contains more water and less sugar, i.e. less concentrated than the cytoplasm, whereas the second solution having water and sugar in the ratio 20. 80 is more concentrated (i.e. contains less water and more sugar) than the cytoplasm. So, if the cell is placed in the first solution, it will swell up by drawing in water due to endosmosis and become turgid. Conversely, in the second solution, the cell will shrink and become crenated due to exosmosis.

[18] What is meant by passive absorption and active absorption?

Ans. Passive absorption means entry of a material into the cell from its surrounding by diffusion. It is driven by the gradient of concentration (for solutes) or electrical potential (for ions) or pressure (for gases).

Active absorption means entry of a material into the cell from its surrounding with the help of a carrier present in the cell membrane and respiratory energy. It is not driving by the gradient of concentration or electrical potential and may even occur against such a gradient.

- [19] Give two examples of active ion absorption by animal cells.
 - Ans. (1) Reabsorption of Na' in the renal tabules.
 - (ii) Absorption of iodide ions (1) by thyroid cells.
- [20] What do you mean by ion pump? Give two examples.

 Ans. The term ion pump refers to carrier proteins of cell membrane that help in active transport of ions across the cell membrane. Example: iodide pump of thyroid cells and sodium pump of renal tubular cells.
- [21] What will happen if (i) some fresh grapes are placed in a concentrated sugar or salt solution and (ii) some dry raisins (kismis) are placed in water? Give reasons.
 - Ans. (i) Fresh grapes contain a dilute solution of sugar. So, when they are placed in a concentrated sugar or salt solution, exosmosis will occur and the grapes will show shrinkage.
 - (ii) Dry raisins (kismis) contain a concentrated sugar solution. Hence, they draw water by endosmosis when placed in water for some time, and swell up.
- [22] What is bulk transport across a cell membrane?

 Ans. Cell membranes some times transport some substances in bulk quantities

into or outside the cell. The substances transported in this way range from macro-molecules to whole cells by pinocytosis or phagocytosis.

[23] Mention the significance of diffusion in plants and animals.

Ans. In plants (i) Exchange of gases through stomata, e.g. intake of O_2 and output of O_2 in respiration, and intake of O_2 and output of O_2 in photosynthesis. (ii) Transpiration of water vapour through stomata. (iii) Passive absorption of salts (or ions). (iv) Translocation of food material (v) Pollination by insects due to spread of scent or aroma in some plants.

In Animals— (i) Transport of respiratory gases between lung and tissues. (ii) Absorption of some nutrients from intestine. (iii) Exchange of materials between tissues and capillaries, e.g. supply of nutrients from blood to tissues and drainage of waste materials from tissues to blood. (iv) Exchanges of materials between RBC and plasma. (v) Insensible perspiration from skin. (vi) Admixture of enzymes and substrates within alimentary canal.

[24] How and why the osmotic pressure of an electrolyte solution differs from that of a non-electrolyte solution?

Ans. The osmotic pressure (OP) of a solution depends upon the total number of solute particles present in the solution. The OP of an electrolyte solution (e.g. aqueous solution of NaCl or KCl in which the solutes are ionised) is higher than the OP of an equimolar non-electrolyte solution (e.g. aqueous solution of glucose or sucrose that are not ionisable). This is because each ion (anion and cation) behaves as a separate particle for OP. The OP of an electrolyte solution is given by the product of the OP of an equimolar non-electrolyte solution and the degree of ionisation of the electrolyte.

[25] Why do molecules diffuse down their concentration gradient?

(J.E.E. 2000)

Ans. The molecules possess some free energy (kinetic energy or energy of motion) due to which they always remain in a state of random motion. Naturally, an area of higher concentration (where there are more number of molecules per unit volume) would possess more free energy than that of an area of lower concentration. According to the second law of thermodynamics, the molecular movement takes place from an area of higher free energy to an area of lower free energy. This is why the molecules diffuse down their concentration gradient, *i.e.* from higher to lower concentration.

[26] How can an Amoeba survive in a hypotonic environment that would destroy a human red blood cell? (J.E.E. 2000)

Ans. When a human red blood cell is placed in hypotonic solution, it swells up due to endosmosis and finally bursts. But an *Amoeba* can survive in an hypotonic environment inspite of continuous entry of water into the cell by endosmosis. This is due to the presence of contractile vacuoles in *Amoeba*, which acts as an osmoregulatory organelle and removes the excess water from the cell, thereby preventing the cell from increasing in size and bursting.

[27] What is plasmolysis? (J.E.E. 2000)

Ans. Plasmolysis means shrinkage of protoplasm and its retraction from the cell

wall in a plant cell due to excessive exosmosis, when the cell is placed in a hypertonic solution.

[J.E.E. 1991] (Ams. 3.7 Q-8,15)

[28] What do you mean by incipient plasmolysis? (J.E.E. 1991)

Ans. Incipient plasmolysis is the initial stage of plasmolysis at which the first sign of shrinkage of protoplasm is detectable.

[29] What happens when RBC is placed in distilled water? (J.E.E. 1999)

Ans. When RBC is placed in distilled water, it draws water by endosmosis and hence swells up and eventually bursts.

EXERCISE

	EAERCISE ,
• Ess	ay type or Long answer type:
[1]	What do you understand by diffusion? Describe it with the help of an experiment and discuss briefly the
	physiological importance of it. [J.E.E. 1982] (Ans. 3.1)
[2]	What is osmosis? Discuss the difference between diffusion and osmosis with examples Explain the
	importance of these. What do you mean by isotonic, hypotonic and hypertonic solution?
	[J.E.E. 1982] (Ans. 3.1; 3.2)
[3]	Describe osmosis with the help of an experiment. How plants and animals are benefitted from this process?
[4]	How a herb or seedling stands erect on the soil? [J.E.E. 1980] (Ans. 3.2; 3.7 Q-16) The cytoplasm of a cell contains water and sugar in the ratio of 50 50. If it is placed in two solutions
Tal	having water and sugar in the ratio of (i) 80 20 and (ii) 20 80 respectively, what physical changes will be
	observed in the cell and why? [Tipura H.S. 1982] (Ans. 3.7 Q-17)
[5]	Define diffusion and esmosis Describe their functions in plants of animals (Ans. 3.1; 3.2),
[6]	Discuss the factors affecting permeability of a cell membrane [J.E.E. 1986] (Ans. 3.3)
[7]	Explain with reasons what will happen if (i) some fresh grapes are placed in concentrated salt solution
	and (ii) some dry raisins (kismis) are placed in water. (Ans. 3.7 Q - 21)
[8]	(a) What is passive absorption of particles? (b) Explain the following (i) pressure gradient,
101	(ii) concentration gradient, (iii) electrical gradient [J.E.E. 1987] (Ans. 3.7 Q-13,14) What is diffusion pressure deficit? How is it related to osmosis? (Ans. 3.2)
[9] [10]	Discuss the factors affecting diffusion. (Ans. 3.1)
[11]	Explain the following terms—
1	(1) osmotic pressure, (11) turgor pressure, (111) wall pressure. (Ans. 3.2)
[12]	What is water potential? How the phenomenon of osmosis can be explained on the basis of water potential?
	(Ans. 3.2)
[13]	Explain the fillowing—
	(i) Gibb's free energy, (ii) chemical potential, (iii) solute potential and (iv) pressure potential (Ans. 3.2)
11.42	Discuss the factors affecting osmotic pressure. (Ans. 3.2)
[14]	Describe the process of osmoregulation in freshwater and marine fishes. (Ans. 3.4)
[16]	What do you understand by passive and active absorption? Describe these processes briefly.
1,	(Ans. 3.3)
• B. S	Short answer type:
[1]	(a) State the factors responsible for permeability of cell membrane (b) What is selective permeability?
	[J.E.E. 1988] (Ans. 3.3; 3.7 Q-1)
[2]	What is a semipermeable membrane and how does it differ from a selectively permeable membrane?
	[J.E.E. 1983] (Ans. 3.2)
[3]	Explain what will happen to a fresh water fish if it is placed in sea water. [J.E.E. 1981] (Ans. 3.7 O-11)
141	What will happen if RBC of toad is placed in isotonic, hypertonic and hypotonic solutions?
[4]	(Aas. 3.7 Q-9)
[5]	(a) What fo you mean by endosmosis? (b) What will happen to a marine fish if it is placed in fresh water?
. ,	(Ans. 3.7 Q-6,10)
[6]	What is active transport? [J.E.E. 1989] (Ans. 3.7 Q-3)
[7]	What is isotonic solution? [J.E.E. 1989] (Ans. 3.7 Q-5)
[8]	By what process a cell absorbs water? (a) What do you mean by inicipient plasmolysis? (b) When a solution A having osmotic pressure of 10
[9]	atmosphere is separated with the help of a semipermeable membrane from a solution B having osmotic
	pressure of 7 atmospheres, to which direction the solvent moleculess flow? Give reason
	LLE.E. 1991 (Ars. 3.7 O-8.15)

[10]	Define diffusion, osmosis and facilitated diffusion.	(Ап	s. 3.7 Q-4
[11]	What is meant by exosmosis and endosmosis?	[J.E.E. 1992] (An	s. 3.7 Q-6
[12]	What will happen to a living plant cell, if it is kept in.		
	(i) hypertonic solution and (ii) hypotonic solution?	[J.E.E. 1992] (An	s. 3.7 Q-7
[13]	What is cell osmosis?		
[14]	Why meat or fish sprinkled with salt remains free from moulds and bact		
(1.61	State the relationship between different program deficit construction	[J.E.E. 1992] (An	
[15]	State the relationship between diffusion pressure deficit, osmotic pressu	re and turgor pressur	
			(Ans. 3.2)
[16]	Give the mathematical expression for water potential.		(Ans. 3.2)
117	How osmotic pressure, diffusion pressure deficit and water potential of solu	ition are related to cor	
11	of the solution?		(Ans. 3.2)
[18]	What is normal saline? How amphibian normal saline differs from mam	alian normal saline?	
			(Ans. 3.2)
[19]	Why molecules diffuse down their concentration gradient?	[J.E.E. 2000] (Ans.	3.7 Q-25
[20]	How can an Amoeba survive in a hypotonic environment that would des	troy a human red ble	ood cell?
		[J.E.E. 2000] (Ans.	3.7 Q-26
[24]	What is plasmolysis?	(Ans.	3.7 Q-27
[22]	What do you mean by osmoconformers and osmoregulators?		(Ans. 3.4)
[23]	What are ionocytes of gill membrane? How do they differ in fresh water		
[24]	What happens when RBC is placed in distilled water?	[J.E.E. 1999] (Ans.	3.7 Q-29
• C.	Distinguish between:		
		1 - D D 400E	
[1]	Diffusion and osmosis.	[J.E.E. 1985]	
[2]	Osmosis and absorption.		(Ans. 3.3)
[3]	Diffusion and active transport.	[J.E.E. 1984]	
141	Active absorption and passive absorption.	*	(Ans. 3.3)
• D.	Write brief notes on:		
[1]	Diffusion		(Ans. 3.1)
[2]	Osmosis		(Ans. 3.2)
[3]	Plasmolysis		(Ans. 3.2)
[4]	Facilitated diffusion		(Ans. 3.1)
[5]	Active absorption		(Ans. 3.3)
[6]	Passive absorption		(Ans. 3.3)
[7]	Osmoregulation		(Ans. 3.4)
[8]	Cell of cell osmosis		(Ans. 3.2)
• E.	Complete the sentences with suitable words:		
[1]	Exchange of O, and CO, across the cell membrane occurs by the process	of .	
[2]	Animal cell swells up when kept in solution.		
[3]	Energy requiring process of absorption is called		
[4]	Absorption of water by a cell occurs by		
[5]	Incipient plasmolysis is the stage of plasmolysis.		
[6]	Plasmolysis in seen in cells.		
171	ion channels help in absorption of ions.		
[8]	lon pumps help in absorption of ions.		
[9]	Osmotic pressure of a solution is proportional to its concentration		
[10]	Diffusion and osmosis are processes.		
• F. F	Multiple choice type questions: Select and write the correct answer from	those given in the pa	rentheses
	for completing the following statements.:		
[1]	In diffusion, molecules move from (higher to lower concentration/	lower to higher conc	entration)
[2]	Animal cells when kept in hypotonic solution (shrink/swell/remain	n unaltered).	
[3]	Water enters into root hairs from soil by (diffusion/osmosis/root p	ressure).	
[4]	Active transport energy expenditure (requires/does not require)		
[5]	In osmosis, solvent molecules move from solution (more concentr	ation to less concent	rated/less
163	concentrated to more concentrated).		
[6]	Osmosis is process (a passive / an active)		

- [8] Water molecules pass through membrane (pores / channels / pumps)
- [9] Gases diffuse through ____ of cell membrane. (pores / lipid matrix)
- [10] Deplasmolysis occurs due to ___ (exosmosis / endosmosis).

● G. Put (✓) mark on Yes / No for correct answers:

- [1] Osmosis is driven by metabolic energy. Yes/No.
- [2] Active transport requires carriers. Yes/No.
- [3] Plasmolysis occurs due to endosmosis. Yes/No.
- [4] Facilitated diffusion is an active process. Yes/No.
- [5] Fresh water fishes do not drink water. Yes/No.
- [6] The body fluids of marine bony fishes are hypertonic to sea water Yes/No.
- [7] Sharks accumulate osmolytes in their body fluids. Yes/No.
- [8] All marine invertebrates are osmoregulators. Yes/No.
- [9] The bigger the molecule, the greater is the rate of its diffusion Yes/No.
- [10] Cell wall of plant cells is a semipermeable membrane. Yes/No.

Answers to Q. Nos. E. F. G.

- E. [1] Diffusion [2] Hypotonic. [3] Active absorption. [4] Osmosis. [5] Initial [6] Plant. [7] Passive. [8] Active. [9] Directly. [10] Passive.
- F. [1] Higher to lower concentration [2] Swell [3] Osmosis, [4] Requires [5] Less concentrated to more concentrated
 - [6] A passive. [7] may require. [8] Pores. [9] Lipid matrix [10] Endosmosis.
- G. [1] No. [2] Yes. [3] No. [4] No [5] Yes [6] No [7] Yes. [8] No [9] No. [10] No

Enzymes

Topics Discussed: Definition: Introduction, Chemical nature, Properties; Types (classification); Mechanism of action, Allostensm, Factors affecting (regulation of) enzyme action; enzyme inhibition

4.1. Definition: Introduction

Enzymes are protein catalysts for chemical reactions in biological systems.

The term 'enzyme' was coined by **Kuhn** in 1878 from the Greek word *en+ zyme* meaning *in yeasts*. Then the German chemist **Eduard Buchner** (1897) discovered the presence of enzyme in cell-free extracts of yeast which ferments sugars and called it zymase. Later, **Sumner** (1926) suggested that *enzymes are proteins*.

All living organisms (biological systems) continuously undertake numerous chemical reactions to maintain the various life processes. Most of these biochemical reactions would occur very slowly, were these not catalysed by the enzymes. It is due to the presence of enzymes, that the biochemical reactions can proceed quite rapidly at a relatively lower temperature. Moreover, the enzymes are produced by the living cells; hence, enzymes are also known as biological catalysts. Unlike inorganic (non-protein) catalysts, an enzyme displays a high degree of specificity, i.e. each enzyme catalyses a small number of reactions, often only one. Enzymes are thus, reaction specific catalysts. Since most of the biochemical reactions are enzyme catalysed, a living organism must contain a large number of different enzymes. Several hundreds of enzymes are now known to exist.

4.1.1. SITE OF ACTION OF ENZYMES:

Enzymes are synthesised by living cells. Previously, the activity of an enzyme was believed to be dependent on the presence of intact cells, *i.e.* enzymes were thought to act within living cells only. This is because, at that time the enzymes could not be isolated and extracted from the cells successfully. In 1897, Eduard Buchner developed the technique for isolation of enzymes and showed that an enzyme can catalyse a reacion *in vitro* (*i.e.* outside the cells, under artificial conditions in the laboratory) as well.

In our body, majority of the enzymes act within the cells where they are synthesised; these might be called as **intracellular enzymes** or **endoenzymes**. Most of the metabolic enzymes belong to this class. Some other enzymes act at extracellular sites after being secreted from the cells of their origin and carried to their site of action. Examples of this are the digestive enzymes that act within the lumen of alimentary canal after being carried there from various digestive glands. The second group of enzymes might also be designated as **extracellular enzymes** or **exoenzymes**.

4.1.2. CHEMICAL NATURE OF ENZYMES:

All enzymes are chemically protein in nature. Some of these are simple proteins that do not require any additional factor for their activity. An example of such enzyme is chymotrypsin. On the other hand, most of the enzymes are conjugate proteins that are made up of a protein part called apoenzyme and a non-protein part called co-factor. The protein apoenzyme alone does not show the activity of the enzyme and it gains catalytic ability only when the non-protein cofactor is bound to it. The cofactor may be an organic molecule or a metal ion (e.g. Mg'', Mn'', Ca'', Zn''etc.) If an organic cofactor is bound loosly to the apoenzyme (so that it can be easily separated by dialysis), it is called coenzyme, whereas those bound very tightly to the enzyme protein are called prosthetic groups. Coenzymes are often vitamin derivatives. The complete conjugate protein enzymes are often called holoenzymes. Some enzymes are synthesised in the form of inactive precursors called proenzymes that are stored in the cells as zymogen granules. These proenzymes are converted to their active forms prior to action. Examples of proenzymes are peposinogen, trypsinogen etc. that are activated to pepsin and trypsin respectively.

• Isozymes: Physically distinct forms of the same enzyme are called isozymes (or isoenzymes). Thus, isozymes are those enzymes that catalyse the same reaction inspite

of the difference in their physical, chemical and immunological properties.

• Ribozymes: Unlike most other enzymes which are proteins, a few RNA molecules can work as enzymes in prokaryotes. These RNA-enzymes are called ribozymes.

4.1.3. PROPERTIES OF ENZYMES:

Enzymes exhibit the following properties:

[1] High molecular weight and colloidal nature: Enzymes have high molecular weight as compared to that of the substrates (reactants or substances acted upon by enzyme). Enzymes are proteins, hence they are colloidal in nature and exhibit the properties of colloids.

[2] Activation energy of reactions: Enzymes lower the activation energy of the

reaction they catalyse.

[3] Specificity: Enzymes are specific in the reactions they catalyse. Normally, an enzyme catalyses only one reaction or one type of reaction. Intracellular enzymes usually work on only one substrate while certain digestive enzymes act on a class of substrates.

- [4] Reusuable: Enzymes are not destroyed by the reaction they catalyse and so they can be used again and again like catalysts. However, this does not mean that the enzymes are used indefinitely because they are very unstable and are readily inactivated by heat, acid etc.
- [5] Reversible action: An enzyme can work in either direction; hence enzyme catalysed metabolic reactions are generally reversible. The direction in which an enzyme works depends on the relative amounts of substrates and products. When substrate concentration is higher, the reaction will move forward. Conversely, when the product concentration in higher, the reaction will move in backward direction.
- [6] Temperature sensitivity: Enzyme action is sensitive to temperature changes, i.e. deviation from optimum temperature reduces the rate of enzyme action. At very low temperatures, enzymes become temporarily inactive and the activity can be regained by raising the temperature. But enzymes are permanently inactivated by excess heat,

i.e. enzymes are thermolabile. This is because enzymes are proteins that are irreversibly coagulated and denatured by excess heat (above 45°C)

[7] pH sensitivity: Enzymes are sensitive to pH. Each enzyme has its own optimum pH, i.e. the range of pH at which it works most efficiently. The intracellular metabolic enzymes usally function best around the neutral pH. Excessive acidity or alkalinity impairs enzymes activity. On the other hand, certain digestive enzymes work best at acidic or alkaline pH. For example, pepsin works best in a strongly acidic medium, while trypsin is best active in an alkaline medium

[8] Speed of action: Enzymes work very rapidly. The speed of action of an enzyme is expressed as its turnover number which is the number of the substrate molecules converted into products by one molecule of enzyme per minute. The turnover number of different enzymes vary from 100 to several millions. Some of the fastest enzymes are carbonic anhydrase, catalase etc. The speed (or velocity) of enzyme action is affected by temperature, pH, substrate concentration, enzyme concentration and presence of activators and inhibitors.

4.1.4. DIFFERENCE BETWEEN INORGANIC CATALYST AND ENZYME (ORGANIC CATALYST).

Inorganic catalyst	Enzyme (Organic catalyst)
[1] These are completely stable and	[1] These are unstable and cannot
can be reused indefinitely	be reused indefinitely
[2] They lower the activation energy	[2] They lower the activation energy
to lesser extent.	to a greater extent.
[3] They are not proteins, hence they	[3] They are proteins, hence they
do not have colloidal properties	have colloidal properties.
[4] They are less reaction specific.	[4] They are more reaction specific.
[5] Their molecular weight is lower.	[5] Their molecular weight is higher.

4.2. Types of enzymes: Naming and classification of enzymes

Earlier, enzymes were called by ambiguous and uniformative name such as ptyalin, zymase, trypsin, erepsin etc. Later, these were named by adding the suffix 'ase' after the name of the substrate on which they act, e.g. amylase (which splits anylum or starch), protease (which splits proteins), lipase (that splits lipids) etc. However, a more rational classification and nomenclature of enzymes based on the reaction they catalyse, has been proposed by the *International Union of Biochemistry*. According to this, enzymes are divided into six major classes as follows:

[1] Oxidoreductases: These enzymes catalyse oxidation-reduction reactions. Those catalysing oxidation are again of two types— (i) Oxidases which add oxygen to a substrate, e.g. amino acid oxidase, cytochrome oxidase etc.; and (ii) dehydrogenases which remove hydrogen atoms from the substrate, e.g. succinic dehydrogenase, malic dehydrogenase etc. On the other hand, enzymes catalysing reduction of a substrate by adding hydrogen atoms to it are called reductases, e.g. retinene reductase.

[2] Transferases: They catalyse group transfer reactions, *i.e.* transfer of a specific functional group from one substrate to another, *e.g.* amino transferases (or transaminases), hexokinase, choline acetylase *etc.*

[3] Hydrolases: These enzymes catalyse hydrolytic reactions i.e. breakdown of

large molecules into smaller ones by adding water molecule for splitting specific covalent bonds (hydrolysis), e.g. amylase, peptidase, lipase etc.

[4] Lyases: They catalyse removal or addition of groups from the substrate by mechanisms other than hydrolysis, oxidation and reduction, e.g. carboxylase, fumarase, agrinosuccinase, decarboxylase etc.

[5] Isomerase: These are enzymes catalysing interconversion of isomers, e.g.

phosphohexose isomerase, triose phosphate isomerase etc.

[6] Ligases or Synthetases or Synthases: These enzymes catalyse linking of two compounds by energy requiring reactions, e.g. glycogen synthase, fatty acid synthase etc.

According to this system of classification, an enzyme is named considering both the substrate on which it acts and the type of reaction it catalyses. Each enzyme's name has two parts; the first is the name of the substrate and the second is the type of reaction catalysed, ending with -ase. For example, lactic dehydrogenase is the name of an enzyme which catalyses dehydrogenation (oxidation) of lactic acid.

4.3. Mechanism of action of enzymes:

A substance which is acted upon and changed by an enzyme is called substrate. When more than one substrates are required in an enzymatic reaction, they are called reactants.

Michaelis and Menton (1913) proposed that for enzyme catalysed reactions, the substrate (S) first binds with the enzyme (E) to form a very unstable enzyme-substrate (ES) complex. The ES complex then almost immediately dissociates to liberate the enzyme (which remains unchanged) and the product (P) formed as a result of the change in the substrate. The reaction can be shown as—

 $E + S \rightarrow ES \rightarrow E + P$

Thus, at the end of a reaction, only the substrate is converted into the product, while the enzyme is retained in original form (i.e. unaltered like a catalyst) so the same enzyme molecule is reused in original form (i.e. unaltered like a catalyst) so that the same enzyme molecule is reused several times to change a large number of substrate molecules.

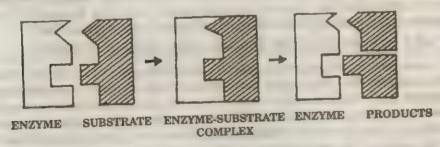


Fig. 4.1: Diagrammatic representation of the mode of enzyme action.

An enzyme catalyses a reaction by lowering the activation energy for the reaction (i.e. the thermal energy required to bring the chemical changes in the substrate molecule) so that the reaction may occur at low energy level. Formation of ES complex by binding of enzyme and substrate is essential for enzyme action. This is helped by the colloidal property of brownian movement of the enzyme molecules. Enzymes being proteins, are colloidal in nature and their molecules exhibit a random zig zag movement called brownian movement. Due to this, there occurs collision between enzyme and substrate molecules as a result of which the ES complex is formed.

Each enzyme molecule has a precise place on its surface to which the substrate molecule becomes attached to form the ES complex. This is called active site or catalytic site of the enzyme because this part of the enzyme actually catalyses the reaction. The active site or catalytic site is extremely specific for the substrate so that each enzyme can bind with a particular type of substrate. The shape of the active site or the positions of the different chemical groups within it ensures that only those molecules having a complementary structure will combine with the enzyme as a substrate. This explains the specificity of enzymes on the basis of which Fischer (1894) proposed a lock-and-key hypothesis (or template model) of enzyme action. According to this, the enzyme and the substrate fit together like a lock and key to form the ES complex.

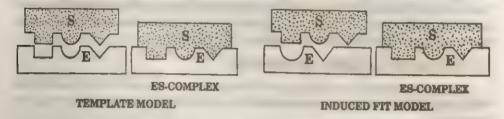


Fig. 4.2: Model for enzyme (E) substratee (S) interaction.

Recently Koshland (1967) proposed the induced fit hypothesis of enzyme action. According to this, the active site of the enzyme is not a rigid, preformed structure to fit the substrate. When the substrate combines with the enzyme, it induces conformational changes in the active site so that the active site attains the final catalytic shape and form.

• Multienzyme system or Complex enzyme :

Some enzymes contain more than one catalytic sites on the same protein macromolecule. Such enzymes are called multienzyme systems or complex enzymes which catalyse different consecutive reactions. These enzymes cannot be fractioned into smaller molecules bearing individual enzyme activities. Examples of such multienzyme systems are fatty acid synthase, pyruvate dehydrogenase etc.

4.3.1. ALLOSTERISM OF ENZYME: ALLOSTERIC ENZYMES

Some enzymes are designed to change the shape of their active site (substrate binding site or catalytic site); this is called allosterism and such enzymes are called allosteric enzymes (allo = different; steric = shape). These enzymes are regulated by certain low molecular weight compounds called allosteric modifiers. These compunds bind to the enzyme at a specific site called allosteric site which is well away from the active site of the enzyme. They modify enzyme activity by causing a reversible change in the structure of the enzyme's active site. This in turn affects the substrate binding ability of the enzyme and thus the enzyme action. Allosteric modifiers may increase or decrease enzyme action and accordingly they are called allosteric activators or allosteric inhibitors respectively.

4.3.2. FACTORS AFFECTING ENZYME ACTION: REGULATION OF ENZYME ACTION

Activity of enzymes (or the rate of enzyme action) is markedly affected by several factors as follows:

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[1] Temperature: Each enzyme is most active at a particular temperature which is called optimum temperature. Most of the enzymes have their optimum temperature between 30-40°C. The ratio by which the velocity of action of an enzyme changes due to 10° C rise of temperature is called Q_{10} value or temperature coefficient of the enzyme. In case of many enzymes the reaction velocity almost doubles with 10° C rise of temperature (i.e. $Q_{10} = 2$). The rate of enzyme action progressively decreases with fall or rise of temperature from the optimum temperature. Decrease of temperature increases the viscosity of the enzyme and reduces its molecular motion. This reduces the chance of its binding with the substrate, thereby lowering the rate of reaction. Rise of temperature upto the optimum level, increases molecular motion, (i.e. chance of binding of enzyme and substrate) and thereby the rate of reaction. However, excessive rise of temperature (above the optimum level), causes decrease of enzyme activity due to denaturation of the enzyme proteins.

[2] pH: The rate of enzymatic reaction depends on pH of the medium. The enzymatic activity is maximum at a particular pH, which is referred to as its optimum pH. The optimum pH for most of the enzymes has between 4-9. The H^+ present in the reaction medium and thus its pH may influence the activity of an enzyme—(i) by altering the ionisation of the active site or substrate molecule, which is necessary for the formation of ES complex, or (ii) by separating the coenzyme from the apoenzyme,

or (iii) by denaturing the enzyme protein.

[3] Enzyme concentration: Increase of enzyme concentration increases the rate of reaction so long as the substrate concentration is in large excess and the enzyme is the limiting factor.

[4] Substrate concentration: The velocity of enzymatic reaction is directly proportional to the substrate concentration upto certain limit, after which increase in

substrate concentration does not increase the velocity of reaction.

[5] Product concentration: Velocity of enzymatic reaction is inversely proportional to the concentration of the product. When large number of product molecules accumulate, the rate of reaction is slowed, and the reaction may move in reverse direction.

[6] Activators and Inhibitors: Presence of certain substances in the reaction medium may increase or decrease the activity of the enzymes; these are called activators and inhibitors respectively. Activators include certain metal ions, (e.g. Fe for cytochrome oxidase, Mg for kinases, Zn for carbonic anhydrase etc.) and allosteric activators (i.e. compounds which bind to a non-catalytic site to increase the activity of the catalytic site). Inhibitors may be of various types and will be discussed later. Activators and inhibitors are also called positive modifiers and negative modifiers respectively.

The rate of enzyme action can be regulated in two ways— (i) by activating or inactivating the already existing enzyme molecules and (ii) by stimulating or inhibiting the gene mediated *de-novo* synthesis of new enzyme (protein) molecules (because more the number of enzyme molecules, greater the rate of action).

4.3.3. ENZYME INHIBITION: INHIBITORS:

Certain chemical agents when present in the medium of an enzyme catalysd reaction, may inactivate the enzyme and slow down the velocity of reaction; this phenomenon is called *enzyme inhibition* and the chemical agents are called *enzyme inhibitors*. Depending on the nature of action of inhibitors, inhibition may be of various kinds as follows:

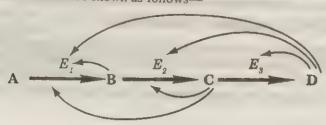
[1] Reversible and irreversible inhibition: If the inhibitor combines with the enzyme temporarily so that the inhibition may be withdrawn or reversed, the phenomenon is called temporary inhibition or reversible inhibition. Conversely, if the inhibitor binds and denatures the enzyme permanently, so that it cannot be removed without loss of activity, the inhibition is called permanent or irreversible because in this case, the inhibited enzyme molecule cannot be activated again. The irreversible inhibitors are poisons for the enzyme.

[2] Competitive and non-competitive inhibition: If the inhibitor molecule is structurally similar to the substrate molecule, they compete for the same active site of the enzyme. Thus, the chance of ES complex formation and velocity of reaction is reduced. This type of inhibition is referred to as substrate analogue inhibition or competitive inhibition and it is of reversible nature because it can be withdrawn by addition of subatrate molecules to the medium. So, the degree of inhibition depends on the relative concentrations of the substrate and inhibitor. An example of competitive inhibition is, inhibition of the enzyme succinate dehydrogenase by malonate (which structurally resembles succinate).

In case of non-competitive inhibition, the inhibitor molucule does not resemble the substrate structurally. It binds to the enzyme molecule outside the active site, thereby preventing the catalytic activity of the enzyme. In this type, the degree of inhibition depends entirely on the concentration of the inhibitor and cannot be varied by changing the substrate concentration. Since the substrate and inhibitor do not compete for the active site of the enzyme, this kind of inhibition is so named. An example of non-competitive inhibition is inhibition of the enzyme glyceraldehyde-3 phosphate dehydrogen ase by iodoacetate. The non-competitive inhibition may be of reversible or irreversible type.

[3] Allosteric inhibition: When an inhibitor binds to the enzyme at a site other than the active site so that the active site is denatured and the substrate cannot bind with the enzyme, the phenomenon is termed allosteric inhibition. Such inhibitors are called allosteric inhibitors and the enzymes influenced by such inhibitors are called allosteric enzymes.

[4] Feed back inhibition (or Product inhibition): The product of an enzyme catalysed reaction may inhibit the enzyme so that the reaction may not continue unnecessarily. This type of inhibition is called feed back inhibition or product inhibition. This type of inhibition is often seen in case of a series of reactions in which an intermediate or the final product may inhibit an early enzyme of the series. In such cases, since the product is a compound which is totally different from the substrate of the inhibited enzyme, the inhibitor cannot block the active site and it must act allosterically. So the feed back inhibition is an example of allosteric inhibition. The feed back inhibition can be shown as follows—



Here, A is the original substrate; B,C, D are the products and E_1 , E_2 , E_3 are the enzymes of the reaction series. B may inhibit E_1 , C may inhibit E_1 and E_2 and D may inhibit E_1 , E_2 , and E_3 .

• Difference between competitive and non-competitive enzyme inhibition. •

Competitive inhibition	Non-competitive inhibition	
[1] It is reversible.	[1] It may be reversible or irreversible.	
[2] Inhibitor and substrate resemble	[2] Inhibitor and substrate do not	
each other in structure.	resemble structurally.	
[3] Inhibitor binds to the active site of	[3] Inhibitor does not bind to the	
the enzyme.	active site of the enzyme.	
[4] Inhibitor cannot bind with the ES	[4] Inhibitor can bind with the ES	
complex.	complex.	
[5] It can be removed by addition of	[5] It cannot be removed by	
substrate.	addition of substrate.	

REVISION

Enzymes— Protein catalysts produced by living cells.

Holoenzyme— A complete conjugate protein type enzyme.

Apoenzyme— The protein part of an enzyme without catalytic activity.

Cofactor— The non-protein active part of an enzyme.

Coenzyme— An orginic cofactor (non-protein part) of an enzyme which is loosely bound to the apoenzyme.

Prosthetic group— An organic cofactor (non-protein part) of an enzyme which is tightly bound with the apoenzyme.

Proenzyme— An inactive precursor of an enzyme.

Isoenzyme (or Isozymes)— Physically different forms of an enzyme.

Multienzyme— A complex enzyme in which several active sites are present on the same apoenzyme.

Ribozyme— An enzyme which is chemically not a protein but a RNA (i.e. a RNA having enzyme activity).

Endoenzymes or Intracellular enzymes— Enzymes that act within the cells where they are produced.

Exoenzymes or Extracellular enzymes— Enzymes that act outside the cells of their origin.

Active site of an enzyme— Catalytic site present on the surface of the enzyme molecule which actually catalyses the reaction.

Allosteric site— Any site of the enzyme other than the active site which can influence the catalytic activity of the active site.

4.4. Matters to Recollect

- Enzymes are also called biological catalysts or protein catalysts or organic, catalysts.
- All enzymes are protein in nature, but all proteins are not enzymes.

- Coenzymes are the active parts of the enzymes.
- Substrates are substances on which the enzymes act.
- Inactive precursor form of enzymes are callect proenzymes.
- Ability of an enzyme to change the shape of its active site is known as allosterism.
- Enzyme action is sensitive to pH and temperature.
- Inhibition of an enzyme by its products is called feed back inhibition.

4.5. Summary

Enzymes are biological catalysts that are produced by living cells but their activity does not depend on the presence of intact cells. All enzymes are protein in nature, some are simple proteins while some others are conjugate proteins in which the protein part is called apoenzyme and the non-portein part is called cofactor (coenzyme or prosthetic group or metal ion activator). The substance on which the enzyme acts is known as substrate. During enzyme action, the enzyme combines with the substrate to from enzyme-substrate complex which reduces the activation energy for the reaction and converts the substrate into the product which splits from the enzyme.

Enzymes show specificity for substrates. Depending on the nature of reaction they catalyse, enzymes are classified into six groups—oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases. Some enzymes show allosterism and are regulated by allosteric modifiers that affect the action of the enzyme by binding with it at an allosteric site (a site different from the active site). The rate of enzyme action is affected by temperature, pH, substrate concentration, enzyme concentration, product concentration and presence of activators and inhibitors.

4.6. Naming / Discovery / Discoverer

- [1] The term enzyme— coined by Kuhn (1878).
- [2] Presence of enzymes in cell free extracts—first showed by E. Buchner (1897) in yeast extracts.
- [3] Formation of *enzyme-substrate (ES) complex* during enzyme action—proposed by L. Michaelis and M. Menton (1913).
- [4] Lock and key hypothesis or Template hypothesis of enzyme action-proposed by E. Fischer (1894).
 - [5] Induced fit hypothesis of enzyme action—proposed by Koshland (1967)

4.7. Answer to special questions

[1] What are aponzyme, coenzyme and isoenzyme? (J.E.E. 1985)

Ans. Apoenzyme— In enzymes which are conjugated proteins, the protein part is called apoenzyme which does not have catalytic activity.

Coenzyme— In a conjugated protein type enzyme, if the non-protein part is a loosely bound organic compound, it is called coenzyme which gives catalytic activity of the enzyme.

Isoenzyme— When different enzyme molecules catalyse the same reaction they are called isoenzymes.

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Differentiate between prosthetic group and cofactor. (J.E.E. 1988)

Ans. Cofactor is the non-protein part of a conjugated protein type enzyme which gives the catalytic activity of the enzyme. It may be a metal ion or an organic compound.

Prosthetic Group is an organic compound which acts as cofactor of an enzyme and remains tightly bound to the protein part of the enzyme (or apoenzyme).

What are meant by active site and allosteric site of an enzyme? 131

Ans. The part of an enzyme molecule where the substrate is bound for the catalytic activity of the enzyme is called active site or catalytic site.

Allosteric site of an enzyme is the part of the enzyme which is located away from active site and when some agent binds to this site the catalytic activity (i.e. the activity of the active site) is altered.

[4] What are substrate, activator and inhibitor of enzyme?

Ans. Substrate of an enzyme is the substance on which the enzyme acts by binding with it.

Activator of an enzyme is a chemical agent which binds to the enzyme to increase its catalytic activity.

Inhibitor of an enzyme is a chemical agent which binds to the enzyme to decrease its catalytic activity.

What is feed back inhibition of an enzyme? What is its utility? [5]

Ans. Feed back inhibition of an enzyme means decrease of enzyme activity due to accumulation of products. In a sequence of enzyme catalysed reactions, an intermediate product or a final end product may inhibit an early enzyme. This type of feed back inhibition of enzyme is very important for preventing (i) unnecessary continuation of the reaction, (ii) accumulation of products and (iii) exhaustion of the substrate.

What are proenzymes? Give two examples. [6]

Ans. Proenzymes are mactive precursor of the enzymes.

Examples—pepsinogen and trypsinogen.

What is an allosteric enzyme? [7]

Ans. Some enzymes possess another site in addition to their active site to which an agent may be bound to modify (inhibit or activate) the enzyme activity. This site is called allosteric site, the agent is called allosteric modifier and such an enzyme is called allosteric enzyme.

What is meant by prosthetic group of enzyme? [8]

Ans. See answer to O-2.

[6]

EXERCISE

Essay type or Long answer type: What is an enzyme? Describe its chemical nature (Ans. 4.1, 4.1.2) [1] Explain the terms enzyme, apoenzyme, cofactor, coenzyme, prosthetic group, holoenzyme and substrate. [2] (Ans. 4.1.2) Classify enzymes with two examples of each class. (Ans. 4.2) [3] What is enzyme inhibition Explain the terms competitive inhibition and non-competitive inhibition of [4] (Ans. 4.3.3) an enzyme. Describe briefly the different properties of enzymes. (Ans. 4.1.3) [5] (Ans. 4.3.2) Discuss the different factors affecting enzyme action.

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[7]	What is feed back inhibition of an enzyme?	· (Ans. 4.3.3)
{8}	Discuss the mechanism of action of enzymes.	(Ans. 4.3)
A D 0	the sale of the sa	
•n. 5	hort answer type:	
[1]		.E.E. 1985) (Ans. 4.7 Q-1)
121	What do you mean by prosthetic group of an enzyme? or What is meant by p	
121	1172	(Ans. 4.7. Q-2)
[3]	What are proenzymes, endoenzymes and exoenzymes? What do you mean by catalytic site and allosteric site of an enzyme?	(Ans. 4.1.2, 4.1.1) (Ans. 4.7, Q-3)
[4] [5]	What are positive and negative modifiers of enzyme?	(Ans. 4.3.2)
[6]	What do you mean by optimum pil and optimum temperature of an enzyme	
[7]	How enzymes are affected by very low and very high temperatures?	(Ans. 4.1.3, 4.3.2.)
(8)	What is an enzyme specificity?	(Ans. 4.1.3)
[9]	Why enzymes are called biological catalysts?	(Ans. 4.1)
[10]	What are lyases and ligases? Give two examples of each.	(Ans. 4.2)
(11)	What do you mean by Q ₁₀ value of an enzyme?	(Ans. 4.3.2)
0.0	. Distinguish between :	
	·	
[1]		.E.E. 1988 (Ans. 4.7.Q-2)
[2]	Apoenzyme and coenzyme.	(Ans. 4.7. Q-1)
[3] [4]	Competitive inhibition and non-competitive inhibition of enzyme Inorgonic catalyst and enzyme.	(Ans. 4.3.3) (Ans. 4.1.4)
1.41	morgonic catalyst and chaying.	(2113: 4:1:4)
●D.	Write brief notes:	
[1]	Lock and key hypothesis of enzyme action.	(Ans. 4.3)
[2]	Multienzyme.	(Ans. 4.3)
[3] 1	Allosterism of enzymes.	(Ans. 4.3.1)
[4]	Competitive inhibition of enzyme.	(Ans. 4.3.3)
[5]	Non-competitive inhibition of enzyme.	(Ans. 4.3.3)
[6]	Product inhibition of enzyme.	(Ans. 4.3.3)
•E C	Complete the sentences with suitable words:	
ELE	Holoenzyme consists of —— and ——.	
[2]	Enzyme catalyses a reaction by lowering —— energy.	
[3]	Inactive precursor of an enzyme is called ——.	
[4]	—— inhibition of an enzyme is reversible.	
[5]	The protein part of an enzyme is called ——.	
[6]	is an exoenzyme.	
[7]	is an endoenzyme.	
[8]	Coenzymes are —— bound to apoenzyme. Enzymes catalysing group transfer reactions are called ——.	
[10]	Physically different forms of an enzyme are called ——.	
()	engineering annulum control of our orangement of the control	
• F.	Select and write correct answer from those given in the parentheses for	completing the following
141 12	statements:	
[2] 11	the non-protein part of an enzyme is called (apoenzyme / isoenzyme / cofe	(topo o to som (budeslands)
131 5	nzymes catalysing breakdown of compounds by addition of water are called wo substrates reacting in an enzymatic reaction are termed as (cofactors /	(ligases lyases/nydrolases)
141 A	vitamin is often associated with an enzyme activity as a — (proenzyme /coc	enzyme / inhibitor)
	ed back inhibition is also called (reversible inhibition / irreversible inhib	
	ypsin is —— (a proenzyme / a coenzyme / an exoenzyme).	product initionion).
	ctive site of an enzyme is the —— site (allosteric/catalytic).	
[8] A	competitive inhibitor binds with the site of an enzyme (active / allosteric	
[9] At	allosteric inhibitor binds to thesite of an enzyme (catalytic / non-cataly	tic).
[10] (Coenzymes are —— bound to the apoenzyme. (tightly / loosely)	

● G Put (✓) mark on Yes/No for correct answers :

- [1] Competitive inhibition of enzyme is irreversible. Yes / No.
- [2] All proteins are enzymes. Yes / No.

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- [3] Allosteric site of an enzyme is same as its active site. Yes / No.
- [4] Enzymes act within living cells only Yes / No.
- [5] Coenzymes are inorganic molecules. Yes / No.
- [6] Apoenzyme is a part of holoenzyme. Yes / No.
- [7] Isoenzymes differ in catalytic avtivity. Yes / No.
- [8] The protein part of an enzyme is called holoenzyme. Yes / No.
- [9] Feed back inhibition is a type of allosteric inhibition. Yes / No.
- [10] Metabolic enzymes are endoenzymes. Yes / No.

Answer:	s to Q. Nos. E. F. G	
E. [1] Apoenzyme, cofactor.	F. [1] Cofactor.	G. [1] No
[2] Activation.	[2] Hydrolase.	[2] No
[3] Proenzyme.	[3] Reactants.	[3] No.
[4] Competitive.	[4] Coenzyme.	[4] No.
[5] Apoenzyme.	[5] Product inhibition.	[5] No.
[6] Pepsin or Trypsin.	[6] Exoenzyme.	[6] Yes.
[7] Hexokinase or Phosphorylase.	[7] Catalytic.	[7] No
[8] Loosely.	[8] Active.	[8] No.
[9] Transferases.	[9] Non-catalytic.	[9] Yes.
[10] Isoenzymes or isozymes.	[10] Loosely.	[10] Yes.

Chromosome

Topics Discussed: Introduction, Definition, Brief historical background, Importance of Chromosome number with examples, Types of Chromosomes—Autosomes and Allosomes, Chromosome Morphology, Size, Karyotype and Idiogram, Structure and Component—Centromere, Kinetochore, Centromeric index, Arm ratio, Chromostid and Chromonema, Coding patterns, Chromomeres, Secondary constriction, Difference between Primary and secondary constrictions, Satellite, Telomere, Chromosome materials—Euchromatin and Heterochromatin, Chemical Composition, Nucleic acids, DNA, DNA types, Structure and replication, RNA types of RNA, Differences between DNA and RNA, Nucleotide and Nucleoside, Chromosome Models: Single stranded, Folded fibre mouel, Solenoid model, Nucleosome Model, Gene—Definition, types, one gene one enzyme theory, one gene one polypetide theory, Operon Concept, Lac-operon and Trytophan operon. Human Chromosome, Banding pattern, DNA fingerprinting, Definition and types, Special types of Chromosomes—Polytene, Famiphrush, B Chromosomes, L Chromosome, M Chromosome, S and E Chromosomes, Megachromosomes, Significance of Chromosomes.

5.1. Introduction

The chromatin reticulum of a nucleus gets dissociated into a definite number of thread-like structures during cell division, called chromosomes (Gr. Chroma = Colour and soma = body). E, Strasburger (1875) first observed chromosomes during cell division. Waldayer (1888), gave the name chromosome for the first time. A complete set of chromosomes in an organism carry all the genetic informations and it is called the diploid set, but in the gametes half of the diploid number, that is haploid number is noted. The major chemical components of chromosomes are nucleic acid and proteins, the nucleic acids are mainly DNA (Deoxyribonucleic acid) andRNA (Ribonucleic acid) and the proteins are either of histone or non-histone types. The functional fragment of the DNA within the chromosome is called gene, which are also called hereditary units. The manipulation of these genes after isolation in living organisms is known as genetic engineering. The prokaryotic chromosomes are simple with DNA only, non-complexed with histone. The cukaryotic chromosomes are complex with all the components. Chromosomes carry the traits of heredity, undergoes mutation and varation and explain the origin of new species from the existing ones.

5.2. Definition

Chromosomes are self-reduplicating nucleoprotein filaments composed of hereditary units called genes. They form the intricate chromatin network of the interphase nucleus.

5.3. Brief historical background

W. Hofmeister (1848) drew the figures of chromosomes from the dividing pollen mother cell of *Tradescantia*. Strasburger in 1875 and Balbiani in 1876 observed that the nucleus gets separated into rod-like bodies. W. Flamming (1879) described the spilitting of these rod-like structures and called these dark stained materials as chromatin. W. Waldeyer (1888) called these structures as chromosomes. Sutton and Boveri (1902) and Boveri (1932), called these chrosmosomes as bearer of hereditary traits. Heitz

(1935), Kuwanda (1939), Geiter (1940) and Kaufman (1948) gave detailed accounts of chromosome morphology. **Dupraw** (1966) gave the ultrastructure of chromosomes. **Kornberg** (1974) gave the modern concept of chromosome ultrastructure in the form of a nucleosome.

5.4. Importance of Chromosome Number

Beneden and Boveri (1887) first discovered that the number of chromosomes in a given species remain constant. This is most significant and of great importance in assigning the phylogeny of the species.

The somatic cells have diploid (2n) number of chromosomes but the gametes have half the diploid set, that is haploid (n) number of chromosomes. This haploid set of chromosome in an organism is also called genome. The fusion of two haploid gametes (male and female) during sexual reproduction again restores the diploid number of chromosomes of the somatic cells.

5.4.1. LOWEST AND HIGHEST CHROMOSOME NUMBER

Lowest: Plant Mucor hemialis (Bread mould) -2n 2

Animal - Ascaris megalocephala univalens (Horse roundworm) 2n = 2

Highest: Plant- Ophioglossum reticulatum (fern) - 2n 1260

Animal – Aulacantha sp (protozoa) – 2n = 1600

The organism with less number and longer size chroniosomes are primitive. But those with greater number and shorter size of chromosomes are comparatively more advanced.

5.4.2. CHROMOSOME NUMBER (2n) OF SOME COMMON PLANTS AND ANIMALS

Plants			Animals	
[1] Haplopappus sp	4	[1]	Ophyrotrocha sp (polychaete)	4
[2] Ustilago sp	4	[2]	Mesostoma sp	4
[3] Spirogyra sp	4	[3]	Mosquito (Anopheles sp)	6
[4] Penicilhum sp	4	[4]	Fruitfly (Drosophila sp)	8
[5] Neurospora crassa	14	[5]	Housefly (Musca sp)	12
[6] Barley (Hordeum vulgare)	14	[6]	Flatworm (Planaria sp)	16
[7] Cucumber (Cucumis sativus)	14	[7]	Toad (Bufo sp)	22
[8] Pea (Pisum sativum)	14	[8]	Grasshopper (Schistocera sp.)	24
[9] Chlamydomonas sp	16	[9]	Frog (Rana sp)	26
[10] Onion (Allium cepa)	16	[10]	Hydra sp.	32
[11] Papaya (Carica papaya)	18	[11]	Bee (Apis indica)	32
[12] Cabbge (Brassica oleracea)	18	[12]	Earthworm (Pheretima sp)	32
[13] Radish (Raphanus sativus)	18	[13]	Alligator	32
[14] Maize (Zea mays)	20	[14]	Starfish (Asterias sp)	36
[15] Watermelon (Citrullus vulgaris)	22	[15]	Cat (Felis domestica)	38
[16] Bean (Phaseolus vulgaris)	22	[16]	Mouse (Mus sp)	40
[17] Tomato (Lycopersicum esculentus	m)24	[17]	Pig (Phocochoerus domesticus)	40
[18] Paddy (Oryza sativa)	24	[18]	Monkey (Macacus sp)	42
[19] Tea (Camelia sinesis)	30	[19]	Rat (Rattus rattus)	42
[20] Sunflower (Helianthus sp)	34	[20]	Rabbit (Orvetolagus sp)	44

Plants .	Animals
[21] Apple (Malus sp) 34	[21] Man (Homo sapiens) 46
[22] Pea nut (Arachis hypogea) 40	[22] Rodent (Funambulus sp) 48
[23] Squash (Cucumis melo) 40	[23] Sheep (Ovis sp) 54
[24] Wheat (Triticum aestivum) 42	[24] Silkworm (Bombyx mori) 56
[25] Avena sp 42	[25] Cow (Bos indicus)
[26] Coffee (Caffea arabica) 44	[26] Goat (Capra hircus) 60
[27] Tobaco (Nicotiana tabaccum) 48	[27] Cattle (Bos indicus) 60
[28] Potato (Solanum tuberosum) 48	[28] Donkey (Equus assinus) 62
[29] Cotton (Gossypium sp) 52	[29] Horse (Equus caballus) 64
[30] Sugarcane (Saccharum officinalis) 80	[30] Guineapig (Cavia porcellus) 64
[31] Yeast (Saccharomyces sp) 4 or 8	[31] Hen (Gallus sp) 78
[32] Aspergillus sp 8 or 16	[32] Dog (Canis familiaris) 78
[33] Orange (Citrus aurantium) 18 or 36	[33] Pigeon (Columba livia) 80
[34] Pear (Pyrus sp) 34, 51 68	[34] Carp (Cyprinus carpio) : 104
[35] Banana (Musa sp) 22, 44, 55 77, 88	[35] Amoeba proteus 500

5.5. Types of Chromosomes

Chromosomes are broadly classified into two types: Autosomes, Allosomes/Sex chromosomes.

[1] Autosomes: Definition: The chromosomes which determine the somatic characters of an organism are known as autosomes or euchromosomes, e.g. 22 pairs of somatic chromosomes of man.

[2] Allosomes: The chromosomes other than autosomes are called allosomes or heterochromosomes. It includes accessory chromosomes or B chromosomes, limited or L Chromosomes, minute or M chromosomes, S and E chromosomes and the sex chromosomes. The sex chromosomes normally determine the sex of an organism. They are either homomorphic, e.g. XX in human female, ZZ in male birds or heteromorphic XY in human male, ZW in female birds.

5.6. Chromosome Morphology

5.6.1. SIZE

The chromosome size is an important characteristic of an organism and varies from species to species. The diameter of chromosomes may vary from 0.2 to 2 μ m, while the length may vary from 0.1 μ m to 50 μ m. In general monocots among plants have large chromosomes while orthoptera (grasshopper) and amphibia among animals have larger chromosomes.

Smallest and largest Chromosomes:

Animal: Smallest: 0.2 µ in some birds.

Largest: 2 mm in Lamprush chromosomes of amphibian oocyte and

polytene chromosome of diptera insects.

Plant: Smallest: 0.025 μ in some algae.

Largest: 32 µm in Trillium govanianum (Monocot)

5.6.2. KARYOTYPE AND IDIOGRAM

Karytype: The photographic representation of all autosomes and allosomes of a somatic diploid cell at mitotic metaphase stage. It can either be symmetrical (chromosomes of similar size) or asymmetrical (chromosomes of variable size).

Idiogram: When the chromosomes are represented diagrammatically and arranged in homologous pairs in the order of decreasing length.

5.6.3. STRUCTURE AND COMPONENTS

The shape of chromosome changes with the different phases of cell cycle. During interphase, the chromosomes remain in the form of fine thread-like network called chromatin threads. But during metaphase and anaphase, they contract and shorten to form distinct rod-like structures. They show distinct arm-like chromatid formed of coiled chromonema and knob like protein particles called chromomeres. There is a primary constriction called centromere, in addition to this, there is a secondary constriction present in some chromosomes, which is associated with nucleolus formation and so it is called nucleolus organiser. A part of chromatid may be pinched off from the 2ndary constriction and it is called satellite, which is devoid of nucleic acid.

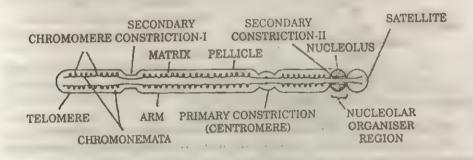


Fig. 5.1: Chromosome morphology

The study of chromosomes is mainly done from shoot tip or root tip of plants (containing the meristematic tissue) or from the pollen mother cells of plants and tissue from sex glands and W.B.C. in animals. The sample is pretreated by heating in acetic acid, which dissolves the spindle fibre and stained with various stains like aceto-orcein, aceto-carmine, giemsa. The smallest fragment is taken on a glass slide and smeared with a cover slip using the squashing technique which forms a single layer of dividing cells. The metaphase and anaphase chromosomes because of their high degree of condensation are the best specimens to study all the morphological characters.

The following structures are distinguished in a condensed chromosome:

[A] Centromeric Constriction or Primary Constriction: Definition: The non-stained notched region of a chromosome containing the centromere is known as primary constriction.

Structure: It appears as a gap in the chromosome, but actually there is no scarcity of chromatin here, it is invisible due to its non-staining property. They contain the centromere and is variable in position, which imparts various shapes to the chromosomes during the anaphasic separation.

[B] Centromere (Gr.: Kentron = centre; Meras = part) Definition: The spherical chromomeric structure at the centre of the primary construction responsible for the attachment of the chromosome to the spindle fibre is known as centromere.

Number: Normally majority of chromosomes have one centromere (monocentric); sometimes chromosomes may break to form acentric fragments which are lost during cell division; dicentric ones are with two centromeres (formed due to translocation) as in wheat or a new centromere may be formed at a later stage called neo-centromere as in maize; polycentric condition is observed in *Luzula*, *Ascaris* and these chromosomes are called holokinetic chromosome.

Structure: The centromere was considered as a gap in the chromosome, until in 1933, Mc Clintock first demonstrated that it has a distinct structure. Tijio and Levan (1950) after pretreatment with oxyquinolines regarded the metaphase centromere to have quadruple nature that is formed of 4 chromomeres joined by inter chromomeric fibre. Lima-de-Faria (1958) stated that the halves of the centromere are identical in

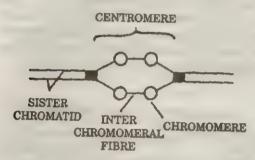


Fig. 5.2: Structure of a Centromere

morphology and function. The chromomeres have a diameter of 0.5 µm and they are composed of repetitive sequences of DNA upto 100 nucleotides long called sat DNA.

Functions: [1] It is the point where the two arms of chromosome meet.

- [2] It determines the shape of the chromosome.
- [3] The microtubules of the spindle gets attached to the contromere and the

anaphasic separation of the chromosome is initiated.

• Classification of Chromosome on the basis of position of Centromere :

The chromosomes can be classified on the basis of the position of centromere, particularly observed during anaphasic monement. They are as follows.

[a] Metacentric (Median centromere): The centromere occurs at the centre of the chromosome which divides the chromosome into two equal arms. It takes up 'V' shaped configuration during anaphase movement e.g, Amphibia, Tradescantia.

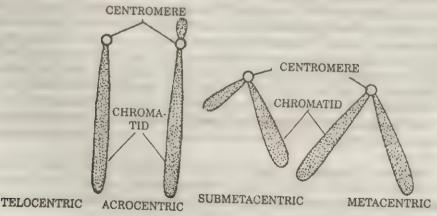


Fig. 5.3: Types of chromosome on the basis of Centromere position

[b] Submetacentric (Sub-median centromere): The centromere occurs very close to the centre of the chromosome dividing it into two unequal arms. It takes up 'L'

shaped configuration during anaphase movement e.g. Choromosome number 2, 9, 10, 12, 17, 18 in man.

[c] Acrocentric (Sub terminal centromere): The centromere occurs very close to the terminal end of the chromosome forming one very long and one very short arm. It takes up 'J' shaped configuration during anaphase movement, e.g. Locust, chromosome IV of *Drosophila*.

[d] Telocentric (Terminal centromere): The centromere is almost terminally situated on a chromosome. The small arm is just like a small dot at one end, the long arm being almost equal to the length of the chromosome. It is of rare occurrence, denoted by Marks (1957) in protozoa.

Arm Ratio: The ratio of length of the long arm to the short arm of a chromosome is called Arm-Ratio. It is a characteristic feature of each chromosome. Metacentric and submetacentric chromosomes have low arm-ratio but in acrocentric chromosome, the arm ratio is high.

[C] Kinetochore: Definition: The protein disc attached to the centromeric chromomeres to which the spindle microtubules are joined.

Structure: There are two kinetochores observed in each chromatid. Each of them is a disc of 0.2 µm attached to 4-7 microtubules. They have trilaminar structure with two outer layers joined to a low density middle layer. It is also called MTOC (Microtubule organization centre).

Function : The kinetochore binds with the microtubule of the spindle fibres. When the two chromatids separate, they move towards the two opposite poles with a force of 7×10^5 dynes due to the depolymerization of the microtubules.

[D] Secondary Constriction (Nucleolar Constriction): Definition: Any

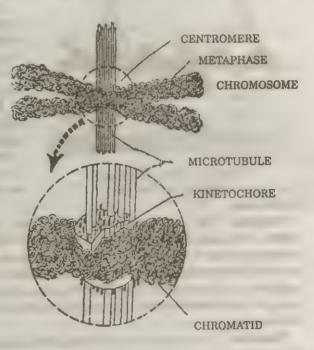


Fig. 5.4: Structure of a kinetochore

constriction other than the primary constriction is termed as secondary constriction.

Structure: They appear as additional constricted zones on the chromosome. They generally are comprising of a pair of chromosomes called nucleolar chromosomes, one or two in number, but they occupy fixed position on the chromosome. The secondary constriction I remain associated with the Nucleolus Organisation region. They remain straight during anaphase movement.

Function: [1] They help in the organization of the nucleolus.

[2] They synthesize m-RNA.

[E] Chromatid & Chromonema: Definition: One of the identical strands of chromosome developing during its replication.

The chromatids at their early stage of condensation is called **chromonema** (chroma = colour, nema = thread).

Structure: Each chromosome is bipartite that is formed of two thread-like chromatids, spirally intertwined, first named by Vejdovsky in 1912. Previously, it was considered that the single chromosome is formed of numerous fibrils and up to 256 such fibrils were denoted under electron microscope. But present studies have revealed that instead of numerous fibres, a single fibre remain in highly coiled and much folded state.

Type of coiling of chromatid: The coiling of chromonema within the chromosome are mainly of two types:

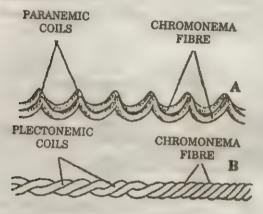


Fig. 5.5 : Coiling of Chromonema A-Paranemic B-Plectonemic

[1] Paranemic Coil: The chromonemal threads are easily separable from their coiling.

[2] Plectonemic Coil: The chromonemal threads are intertwined intimately and cannot be separated easily. The degree of coiling depends on the overall length of the chromosome.

Function: The chromonema is the site where DNA remains packed.

[F] Chromomere: Definition: They are stainable bead-like structures arranged along the

chromosome.

Structure: The chromomeres are present in the early prophase of mitosis and meiosis. They appear as beaded necklace, where the bead like chromomeres are attached to interchromomeric thread. The position of chromomeres are fixed and there may be up to 600 chromomeres visible in one set of human chromosome. They are actually superposed coils as observed under electron microscope and actually represent linearly arranged nucleosome bodies. They are not visible in the tightly coiled metaphase chromosome.

Function: They are the structural component of chromosome but do not actually represent genes.

[G] Telomeres: Definition: The terminal end of chromosome are called telomere. Structure: It was named by Muller (1938). They are formed of heterochromatin and contain repetitive DNA, remains associated with nuclear envelope.

Function: They impart polarity to chromosomes and prevent joining of chromosome fragments.

[H] Satellite: Definition: The terminal round knob-like heterochromatin body beyond the secondary construction of a chromosome is known as Satellite or Trabant.

Structure: The shape and size of satellite is constant in a chromsome and its diameter is same as the chromatid. It is connected to the chromatid by a thin chromatin filament. A chromosome with satellite is called SAT-chromosome (Sat = Sine Acid thymonucleinico, that is without thymonucleic acid or DNA)

Function: There is no specific function but it is just a morphological feature.

REVISION

Chromosome: Compact nucleoprotein thread-like particles formed during cell division.

Chromatid or Chromonemata: One of the two identical halves of a chromosome attached to the centromere.

Chromomere: Stamable nucleoprotein thickenings of a chromosome, which appear as linearly arranged beads.

Centromere: Point of attachment of sister chromatids of a chromosome.

Centromeric Index: Study of the position of the centromere on the different chromosomes of a particular species, i.e. it is ratio of short arm length to that of total chromosome length.

Kinetochore: Plate like structure in the centromere where the microtubules are attached, also called MTOC (Microtubule organisation centre).

Satallite: Heterochromatid bulge of Chromatid beyond the secondary constriction of a chromosome.

Distinguish between Primary Constriction and Secondary Constriction

Points of Difference	Primary Constriction	Secondary Constriction
[1] Frequency	Present in all chromosomes.	Present in one pair of chromosomes in majority of organisms.
[2] Location	It is variable on a chromosome, submetacentric, acrocentric and telocentric chromosomes.	Normally near the terminal end of a chromosome.
[3] Attachment with Spindle	Present.	Absent.
[4] Chromomeres	Four Centromeric chromomeres present.	Chromomeres are absent.
[5] Association	Associated with MTOC.	Associated with NOR.
[6] Satellite	Does not form the satellite.	May form the satellite.
[7] Folding	Folds during anaphase.	Does not fold.

5.7. Parallelism between gene and chromosome :

Chromosomes are hereditary structures formed by the division of the nuclear reticulum during cell division. The chromosomes are formed of nucleic acid and protein, the nucleic acid can be either Deoxyribonucleic acid (DNA) or Ribo nucleic acid (RNA) and proteins are both basic and acidic in nature. They are visible under microscope during cell division.

Genes are the actual hereditary units present within the chromosomes. They are actually the functional fragments of DNA nucleotide, classified on the basis of their function *i.e.* mutation, replication, linkage, crossing over. They are responsible for the transmission of characters through subsequent generations.

The change in chromosome structure is brought about by chromosonal aberration, but genes are modified by gene nutation.

5.8. Chemical Structure of Chromosome:

Nucleic Acid: They are present within the nucleus. They are long chained compounds built of repetitive units of small molecules joined end to end. They unite with protein to from the nucleoprotein particles of the chromosome. Nucleic acids are of two types:

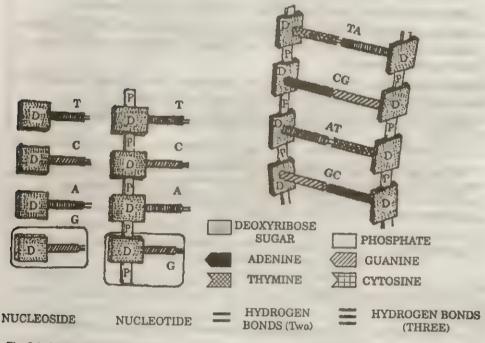


Fig. 5.6: Nucleotide and Nucleoside

Fig. 5.7: Polynucleotide (Diagrammatic Model)

DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid). DNA is found in the nucleus, mitochondria, chloroplastids and other cytoplasmic organelles, whereas RNA is found in cytoplasm and nucleolus.

In nucleic acid, there are three major components, the pentose sugar (deoxyribose in DNA, ribose in RNA), phosphoric acid and nitrogen bases (adenine, guanine, thymine, cytosine in DNA; thymine is replaced by uracil in RNA). The pentose sugar joins with each of four nitrogen bases to form four different nucleosides. The phosphoric acid joins with the nucleoside at the 3'OH and 5' OH groups of the pentose sugar to form the nucleotide. The nucleotides form the basic units of nucleic acids.

Ribose and Deoxyribose nucleosides and nucleotides:

Nucleic acid	Nitrogen Base	Nucleoside	Nucleotide
RNA	Adenine	Adenosine	Adenosine – 3' — monophosphate (3'AMP) Adenosine – 5' - monphosphate (5' AMP) Adenisine 3', 5' - cyclic monophosphate (CAMP)
	Guanine	Guanosine	Guanosine – 5' - monophosphate (5' GMP) Guanosine – 5' - monophosphate (5' GMP)
	Cytosine	Cytidine	Cytidine - 5' - monophosphate (5' - CMP)
	Uracil	Uridine	Uridine 5' monophosphate (5' - UMP)
DNA	Adenine	Deoxyadenosine	Dexyadenosine – 3' - monophosphate (3'dAMP) Deoxyadenosine - 5' monophophate (5 d AMP)
	Guanine 199	Deoxyguanosine	Deoxyguanosine - 5- monophosphate (5' fGMP)
	Cytosine	Deoxycytidine	Deoxycytidine - 5' - monophosphate (5' - dCMP)
	Thymine	Deoxythymidine	Deoxythymidine – 5' monophosphate (5' - dTMP)

DNA (Deoxyribonucleic acid):

DNA is the most inportant chemical compound of living organisms, it is the blue print of life carrying hereditary information from generation to generation. It carries all the important information for controlling all the biological activities like growth, cell division and protein synthesis.

[a] History: Miescher (1869) separated DNA molecule from the nucleus of pus cell and named it as nuclein. Hertwig (1884) proved its role in heredity. Altmann (1889) gave the name nucleic acid. Watson & Crick (1953) proposed the most

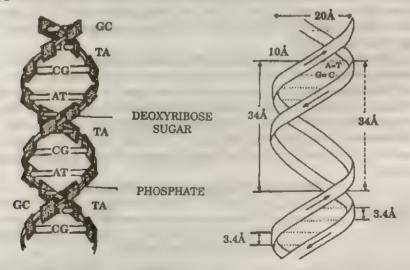


Fig. 5.8: DNA double helix (Diagrammatic)

acceptable double helix model of DNA. Meselson & Stahl (1958) showed that DNA replication is semi-conservative in nature. Jacob & Monod (1961) explained the role of mRNA in protein synthesis and the operon concept.

Shaprio (1969) first published the picture of an isolated gene (lac duplex) **Woodcock** (1973) gave the nucleosome model improved by **Kornberg** (1974).

- [b] Nature: The DNA is a long double stranded molecule found in majority of organisms. It is single-stranded in Coliphage virus, it is triplet in some prokaryotes. It is mostly right handed as observed in A-DNA, B-DNA, C-DNA and D-DNA and left handed in Z DNA DNA is the genetic material of all organisms.
- [c] Morphology: The DNA molecule in eukaryotic cell is thread-like, unbranched and straight, while in prokaryotic cell, mitochondria and plastid, it is circular in shape. The size of DNA is variable from species to species. In bacteria, it is about 1.4 μ m long, but in mitochondria it is 5 μ m. In eukaryotes, they are packed into the chromosomes and the length varies from 50 to 500 μ m.

Classification of DNA on the basis of organisation:

Type	Nature	Helical diameter	Base pairs per turn of 360°	Axial rise (h)
A	Right - handed	23Å	11	2.56Å
В	Right - handed	19Å	10	3.37Å
C	Right - handed	19Å	9.33	3.32Å
D	Right - handed	20Å	8	3.03Å
Z	Left - handed	18Å	12	3.70Å

- [d] Occurrence: DNA is present in viruses, in prokaryotes like bacteria, blue green algae, in the chromosome, centriole, mitochondria and plastids of eukaryotes.
- [e] Chemical Composition: The DNA is a complex macromolecule, consisting of three major components.
- [i] Pentose sugar: It is deoxyribose sugar, where one atom of oxygen is absent in the second carbon atom in comparison to D-ribose sugar. They remain in Furanose ring form, where the 1st carbon atom joins with the oxygen of the 4th carbon atom and thus five carbon rings are formed. It joins with nitrogen base via C-1 OH group with glycoside bond. The phosphoric acid joins to the pentose sugar via C-3 and C-5 OH groups by covalent bonds.
- [ii] Phosphoric acid: It is ortho-phosphoric acid. It is joined to C-3 and C-5 of two successive molecules of deoxyribose sugar. It imparts acidic nature to DNA.
- [iii] Nitrogen bases: The nitrogen bases are two types, viz. purines and pyrimidines.

 Purine: Purines are organic compound containing two carbon rings. They are of two types: Adenine (2 amino 6 oxypurine) and Guanine (6-amino purine).

Pyrimidine: It contains single carbon ring. There are two types of pyrimidines viz. Cytosine (2-oxy-4-amino pyrimidine) and Thymine (2-oxy 4 dioxy - 5 menthyl pyrimidine).

Distinguish between Purine and Pyrimidine:

Character	Purine	Pyrimidine
[1] Ring	Two rings (5C imidazole ring joined to pyrimidine ring)	Single (6C) benzene ring.
[2] Functional group of C-2	With NH, group in adenine, absent in guanine	OH group in both thymine and cytosine.
[3] Direction of carbon in the ring.	Anticlockwise	Clockwise.

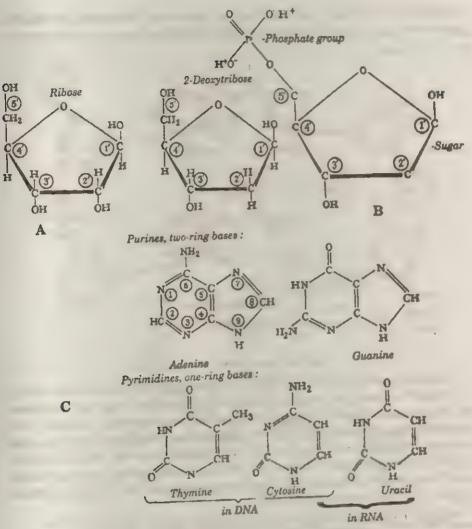


Fig. 5.9: A Structural formulae of Ribosome and Deoxyribose sugars

B -Linkage between phosphate and deoxyribose giving Sugar phosphate

C-Structural formulae of nitrogen bases.

5.9. Watson and Cricks' model of DNA:

In 1953, J. D. Watson, F.H.C. Crick and M. Wilkins proposed the most widely accepted model of DNA based on Chargaffs' model (1951), which states that in DNA, the A = T nucleotide is always equal to $G \equiv C$ nucleotide. According to them, the DNA is a double stranded structure, where each strand is made up of 4 types of nucleotides (viz. deoxyadenylate, deoxyguanylate, deoxycythylate and deoxythymidylate) joined end to end and twisted in plectonemic fashion. The orientation of the two strands is antiparallel, i.e. if the sequence of arrangement for the left strand is 3' to 5' upwards, than the sequence of nucleotide for the right strand will be 3' to 5' downwards. Hence the deoxyribose sugar of the terminal nucleotide at 3' end of the left strand will

correspond to the sugar at the 5' end on the right strand. The coiling of the DNA represent two grooves placed alternately, they are the major groove and minor groove.

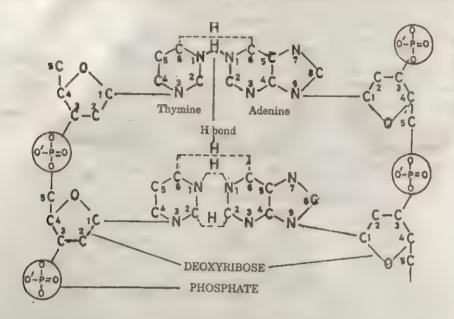


Fig. 5.10: Portion of DNA polynucleotide

The arrangement of the DNA double helix is like a spiral staircase, where the railings are formed by joining of alternate molecules of deoxyribose sugar and phosphoric acid, the steps are formed by joining of purine and pyrimidine bases. Adenine (A) is joined to thymine (T) with the help of two hydrogen bonds while guanine (G) is joined to cytosine (C) by three hydrogen bonds. The distance between two strand is fixed *i.e.* 20Å. Each base pair forms an angle of 36° with the previous one, so in a complete turn of 360°, there will be 10 base pairs, separated by a distance of 3.4Å. The helical distance of DNA in a 360° complete turn is 34 Å,

Watson, Crick and Wilkins got Nobel prize in 1962 for this model.

Important DNA types:

P-DNA: Palindromic sequence is same when read from both side e.g:

Selfish DNA: Repetitive areas of DNA not involved in transcription (Protein synthesis).

Extra Nuclear DNA: The DNA strand remaining outside the nucleus e.g.; Mt (Mitochondrial) DNA; Cp (Chloroplast) DNA.

J-DNA (Junk DNA): The DNA nucleotide which is varying from person to person.

Linker DNA: It is 54 base pairs in length joining 2 nucleosomes.

Promiscuous DNA: The DNA segments moving within cell organelles.

5.10. Replication of DNA:

The formation of a new DNA strand using the parent strand as a template is known as DNA replication. It is semi-conservative in nature as denoted by **Meselson & Stahl** (1958). The process is described below:

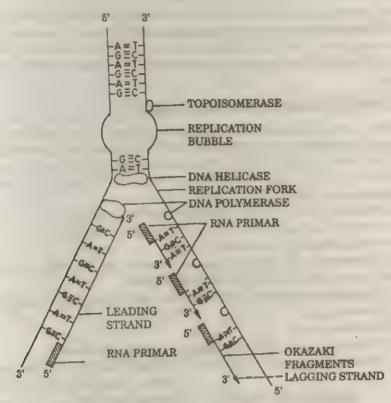


Fig. 5.11: Replication of DNA

- [i] DNA replication takes place during the interphase between the two mitotic cycles. The replication is semi-conservative mostly, but in case of repair, it is non-conservative in nature.
- [ii] The nucleotides of DNA viz. AMP, GMP. CMP.TMP are phosphorylated to form ATP, GTP, CTP an TTP with the help of enzyme phosphorylase.
- [iii] The replication starts at the specific point called the initiation point recognised by the respective initiation protein. It starts with a nick or incision made by endonuclease.
- [iv] The two strands of the DNA double helix unwind with the help of a DNA unwinding protein and an enzyme helicase. This unwinding may be followed by interwining because of the natural tension of the DNA, this is prevented by the superhelix relaxing protein. Moreover, the enzyme topoisomerase cut and rejoin the DNA double helix at several points resulting in the formation of replication bubbles. They finally end into Y-shaped replication fork.
- [v] A RNA primer (upto 200 nuleotide long) is synthesized by the DNA template close to the origin of replication with the help of enzyme RNA polymerase.

[vi] The DNA nucleotides are then added to the 3' end of the RNA primer by the enzyme DNA polymerase III. The RNA primer is then degraded with the help of enzyme DNA polymerase I and replaced by a short DNA segment, which gets joined to the DNA strand by DNA ligase forming a complementary DNA strand called leading strand.

[vii] The other parental strand synthesizes small DNA fragments (upto 1000 bases) called **Okazaki** fragments. These fragments are attached to RNA primers and called the lagging strand. Later, these fragments are joined by polynucleotide ligase.

[viii] The DNA replication can be unidirectional or bidirectional from the point of origin.

5.11. RNA [Ribonucleic acid] and its types:

RNA is mostly a single-stranded molecule containing the ribose sugar and the nitrogen base uracil in place of thymine. In Reo virus, the RNA is double-stranded. RNA is mainly synthesized by DNA (excepting RNA viruses, where DNA is synthesized by RNA). It is accumulated in the nucleolus and is transferred to the cytoplasm via nuclear pore.

- [a] Nature: RNA is formed of many nucleotides joined end to end It is mostly single stranded, non-helical and rarely genetic in nature. The RNA content of a cell is variable depending upon its metabolic activity.
- [b] Occurrence: The RNA remains in the nucleus and also in the cytoplasm. The largest fraction remains associated with the ribosome.
 - [c] Chemical composition: RNA includes mainly three types of components:
 - [i] Ribose sugar.
 - [ii] Phosphoric acid.
 - [iii] Nitrogen bases like adenine, guanine, cytosine and uracıl.
 - [d] Types: Messenger RNA (m-RNA); Transfer RNA (tRNA); Ribosomal RNA

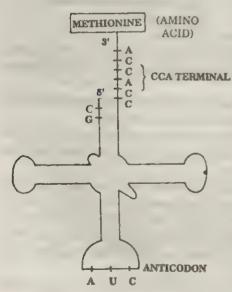


Fig. 5.12 : Methionine t-RNA

(r-RNA); Small nuclear RNA (Sn-RNA); Heterogenous nuclear RNA (hn-RNA); Small stable RNA (ss-RNA); Catalytic RNA (C-RNA); Primer RNA (P-RNA); Guide - RNA (g-RNA).

[i] mRNA: Structure: They are formed from the DNA by transcription. They are represented by a linear chain of nucleotides (900 - 12000 in number). They exhibit splicing off of repetitive sequences and poly-adenylation. They constitute 6-10% of cellular RNA.

Function: They are transferred to the cytoplasm and help in the synthesis of polypetide by the process of translation.

[ii] t-RNA: It is also called soluble - RNA.

Structure: The taRNA; was given the model of a clover leaf by Holley et al.

(1965). According to this structure, there is an anticodon (for fitting with the codon of m-RNA) the free CCA terminal bearing the amino acid. They have 70-80 nucleotides. They include 10-15% of cellular RNA.

Function: They help in carrying the amino acid towards the DNA template during translation.

[iii] r-RNA: Structure: The r-RNA is associated with the ribosome. They contain 1500-5500 nucleotides, consisting of bondless N₂ bases and also some coiled regions where the N₂ bases are joined by hydrogen bonds. They account for 80% of cellular RNA.

Function: They form the Nucleolar Organization region and also help in the binding of the m-RNA with the ribosome during protein synthesis.

[iv] Sn-RNA: They are fromed during protein synthesis, formed of 90-300 nucleotides. They help in processing of m-RNA.

[v] hn-RNA: They are first synthesized from DNA and on processing like splicing and polyadenylation, they form m-RNA. They have a sedimentation coefficient of 8S (Weinberg. 1973) and a molecular weight not exceeding 107 units.

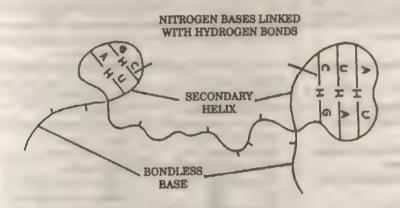


Fig. 5.13: Chemical structure of r-RNA

[vi] SS-RNA: They have 90-300 nucleotides and help in the synthesis of ribonucleoprotein particles.

[vii] c-RNA: The other name for ribozyme, helping in the catalysis of histochemical reactions.

[viii] p-RNA: They are synthesized by the DNA template, at the initiation of DNA replication. Later they are replaced by the complementary DNA strand.

[ix] g-RNA: The mitochondrial RNA which determines the size of m-RNA during the process of transcription.

[e] Comparison between RNA types:

Points of Distinction	m-RNA	t-RNA	r-RNA
[2] Molecular Weight [3] Origin	5%	15%	80%
	5,00,000	25,000	40,000 - 1,00,000
	DNA	DNA	Nucleolus
	900 - 1200	100	1500 - 5500

Points of Distinction	m-RNA	t-RNA	r-RNA
[5] Structure	Single stranded (with minimum repetitive sequences) containing the triplet codons.	Single stranded folded like clover leaf with CCA terminal for the amino acid and the anticodon.	Single stranded with bondless bases, coiled at some areas, appearing double stranded, exhibi- ting bonding
[6] Function	Carry the genetic information from DNA to the Cotoplasm.	Carries the amino acids and initiates translation.	between base pairs Synthesizes ribosomal protein and binds the m-RNA - t-RNA with the ribosome.

[g] Distinguish between DNA and RNA:

Points of Distinction	DNA	RNA
[1] Nature	It is the usual genetic material.	It is the genetic material only in some viruses.
[2] Number of strands	It is usually double stranded	It is usually single stranded
	(Single stranded in the	(Viruses like Reovirus have
	virus Ф x 174).	double stranded RNA).
[3] Pentose sugar	It is deoxyribose sugar.	It is ribose sugar.
[4] Nitrogen bases	They are adenine, guanine,	They are adenine, guanine,
	thymine and cytosine.	uracil and cytosine.
[5] Pairing of nitrogen	This is throughout the	This is observed only at the
bases.	length of the molecule.	helical regions.
[6] Uncommon bases	There are few uncommon	There are more uncommon
	bases.	bases due to methylation.
[7] Types	There are mainly five types	There are mainly of seven
	A-DNA, B-DNA, C-DNA	types r-RNA, t-RNA,
	D-DNA and Z-DNA.	m-RNA, ss-RNA, hn-RNA,
		Sn-RNA and c-RNA.
[8] Distribution	It is mainly present in the	It is formed in the
	chromosomes of nucleus	nucleus and is transferred to
	and outside the nucleus it is	cytoplasm. Also present in
	present in the mitochondria	nucleolus, ribosome and
	and chloroplastid.	cytoplasm.
[9] Denaturation	Denaturation is partially	It is completely and
	reversed when cooled slowly.	instantaneously reversed.
[10] Replication and	The DNA on replication	They do not replicate or transcrip
transcription	forms DNA but on	normally. Some viral RNA can
	transcription forms RNA.	produce DNA by reverse
		transcription.
[11] Number of The number of nucleotides		The number of nucleotides
nucleotides may be upto 4.3 millon.		do not exceed 12,000.
[12] Function	The genetic messages are	The message of the DNA
	encoded in DNA which	is translated into
	are transferred to m-RNA.	polypeptides.

[h] Points of Similarities between DNA and RNA:

- [1] They both contain adenine and guanine as the purine bases.
- [2] Sometimes RNA contain genetic information like DNA in some RNA viruses.
- [3] They have the phosphoric acid.
- [4] The pentose sugar is present in both of them.

5.12. Chemistry of chromosomes

The eukaryotic chromosome contains DNA, RNA, histone (basic) and non-histone (acidic protein) along with minerals like Ca, Mg. Fe etc. The nucleoprotein complex of the chromosome is formed of 90% DNA basic protein complex and rest 10% RNA acidic protein and the ratio of DNA and basic protein is almost 1:1 in majority of plants and animals. The basic protein is mostly histone and protamine in nature consisting of amino acids like lysine, arginine and histidine. There are five major types of histone proteins—H₁ (m.w. 21,500 rich in lysine); H_{2A} and H_{2B} (m.w. 14,004 and 13,774, rich in lysine); H, and H, (m.w. 15,324 and 11,284 rich in arginine). The histones are bound with linker DNA. The acidic protein is non-histone in nature, rich in amino acids like tryptophan and tyrosine. RNA is produced from the DNA and later migrate to cytoplasm for polypeptide synthesis. The mineral ions like Mg2 and Ca2 stabilize the structure of chromosome.

5.13. Chromosome models

Chromosome consists of DNA and proteins, but the actual arrangement is explained with the help of various models which explains the packaging of DNA within the folds of specific proteins. These are as follows:

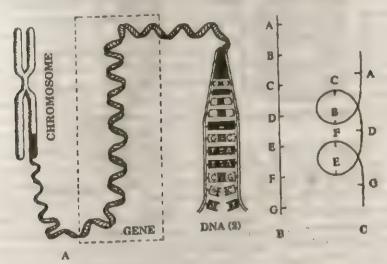


Fig. 5.14: Chromosome Models A Folded fibre model B Single strand C Cycloid model

[1] Unineme Model (Taylor 1957):

The chromatin is fibrous in nature whose diameter is not uniform and interrupted with knob-like structures. The folding of the fibre takes place in a specific manner. The variation in folding causes change in the diameter of the chromatid during various stages of cell divison. During metaphase it is 300Å. But at interphase, it is 230-250Å. Each chromatid consists of a single DNA helix associated with basic protein. Those DNA is about 1 - 8 mm. long in each eukaryotic chromatid and so it is compacted upto 7,000 times for remaining within the chromosome.

[2] The Cycloid model (Calan and Lloyd 1960):

This model states that the single thread of DNA bent repeatedly to form circular loops or cycloids at regular intervals, there by accommodating the long DNA strand within the chromosome. This model is ideal to explain replication and transcription activities of DNA. It also explains how the single DNA strand can be multi-stranded as observed in lampbrush chromosome.

[3] The Folded Fibre model (Du Praw, 1966 and Cummings, 1971):

According to this model, there is a highly folded double stranded DNA thread present within a single chromatid. The chromatids remain attached to the centromere up to the anaphase stage of cell division. The DNA supercoil exhibit a definite organizational pattern, the basic unit is formed by the coiling of type A fibre having a diameter of 80 - 100 Å, which is undergoing further coiling to form the type B fibre with a diameter of 200 -300 Å. The coiling of the DNA double helix are stabilized by the cross linkage between proteins and the non-DNA components normally remain interparsed in the DNA double helix. The packing in the chromatid indicate DNA replication to form a new chromatid.

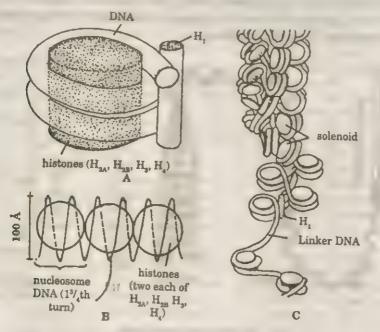


Fig. 5.15: Nucleosome [A] & [B] Units of Nucleosome model [C] Solenoid model

[4] The Solenoid Model (J. O. Thomas, 1974):

This model is a first step towards the formation of a nucleosome. It states that the DNA supercoil shows primary and secondary coiling to form a solenoid (300 Å

diameter) surrounding the core particles represented by histone beads. There are 166 base pairs present in that part of the DNA surrounding the histone core.

[5] The Nucleosome Model (R. Kornberg, 1974 and P. Outdet, 1975):

This model denotes the close relationship between the DNA and protein, present within the chromosome. According to this model, the chromatin is like a string of beads (11 µm diameter). The beads are represented by discrete units called **Nucleosomes** and are connected by a DNA duplex called the linker DNA. The monomer of nucleosome comprises of 200 bases in an average (lowest in *Aspergillus* - 154 and highest in Sea Urchin - 241) surrounding the histone core by 1½ turn. The histones comprise of two copis of each of H_{2A}, H_{2B}, H₁ and H₄, forming the **Nucleosome Octamer**. The H₁ subunit is also associated with the nucleosome as a backbone helping in the scaling of the DNA. The duplex are distinctly divided into two parts, the part surrounding the histone, consisting of 146 base pairs and that part linking two histones with 8-114 base pairs. For this reason, the number of functional base pairs vary in a nucleosome DNA duplex. The assembly of nucleosome particles is brought upon by a nucleoprotein called nucleoplasmin.

5.14. Gene

Definition: Gene is a functional fragment of DNA nucleotide of synthesizing a specific protein and acting as the unit of inheritance.

DEVELOPMENT OF GENE CONCEPT

The structure and function of gene was denoted by several scientists and the gradual development of the concept is illustrated below:

- [1] **Johannsen** (1903) introduced the term gene in place of the factors denoted by Mendel.
- [2] Garrod (1909) studied in details the 'Inborn errors of metabolism' in human and concluded that diseases like phenylketonuria (PKU) or alkaptonuria are due to absence of enzymes phenyl alanine hydroxylase and homogentisic acid oxidase causing accumulation of phenyl pyruvic acid in blood and homogentisic acid in urine respectively. This observation suggested that the mactivation of certain genes caused the deficiency of these enzymes.
- [3] Belling (1928) suggested that the chromomeres arranged linearly as a series of granules on the chromatid are represented the genes.
- [4] **Beadle and Tatum** (1941) denoted the 'One gene one enzyme' theory in the fungus *Neurospora crassa*. The synthesis of arginine is a multistep process and the wild strain in which all the enzymes were present was called prototrophs, which grow in minimal medium. But the mutants developing from the prototrophs, which could not grow in minimal medium was called auxotroph. This was because they lacked some specific enzyme required for the biosynthesis of arginine. The absence of such enzymes was due to inactivation of specific genes by mutation, which clearly indicate the 'one gene one enzyme' hypothesis.
- [5] V. Ingram (1957) indicated the expansion of the previous theory and proposed the 'One gene-one polypeptide theory'. He observed that in human the normal haemoglobin (HbA) contained the 2α and 2β protein chains in the globin portein, but in Sickle-cell anaemia (Hbs), the 6th amino acid, glutamic acid in the β chain is replaced

by valine causing the formation of sickle shaped RBC. Thus one gene controls the activity of one polypeptide directly.

[6] Calan and Lloyd (1960) denoted in the Lampbrush chromosomes that each loop was fromed of two types of genes, the Master gene and Slave gene. The activity of the latter is controlled by the former genes.

[7] F. Jacob and J. Monod (1961) while studying catabolism of lactose in Escherichia coli denoted a unique model of gene regulation called the Operon Model.

It is also called Lac-Operon. The genes are as follows:

[a] Regulator Gene: (I) It is also called inhibitor gene, it codes for a repressor protein which has two binding sites, one binding with the operator gene, while the other binding with the inducer (lactose).

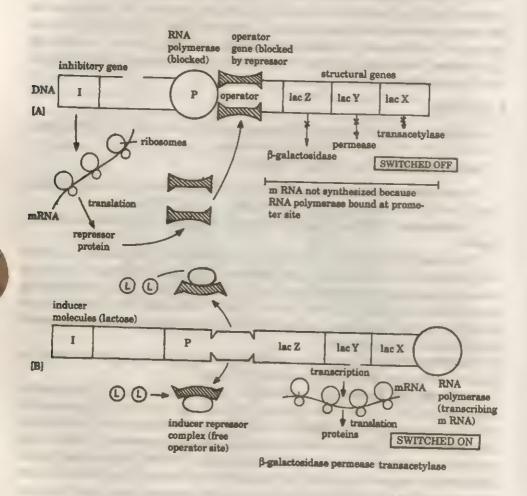


Fig. 5.16: Lac operon model of gene regulation in bacteria (a) Operon in switched off position with repressor bound to operator

(b) Operon in switched on position with repressor inducer complex that removes repressor to free the operator site.

[[]b] Promoter Gene (P): It is the point where the RNA polymerase is associated and operator gene is controlled.

- [c] Operator Gene: (O): This gene interacts with the repressor protein and prevents the activity of the structural genes.
 - [d] Structural Genes: In a lactose operon there are three structural genes:

Lac X coding for enzyme transacetylase.

Lac Y coding for enzyme permease.

Lac Z coding for enzyme β-galactosidase.

5.14.1 OPERATION OF LAC OPERON:

The repressor protein produced by regulator gene binds with operator gene, the structural genes cannot work and the process is switched off. The adding of lactose binds with the repressor and the process is switched on.

The **Tryptophan operon** is another operon with five structural genes and it explains feed back repression. The repressor protein released by the regulator gene cannot bind with the operator and it is called apo-repressor, which keeps the process switched on. But Tryptophan, when added binds with apo-repressor and called co-repressor, switches off the process.

Shapiro et. al (1969) first purified lac-operon and observed it under electron microscope! At the production of the latter of the microscope!

[8] Glover and Hogness (1977): They denoted that the structural genes can control the activity of many polypeptides, so the One gene one polypeptide was replaced by One gene many polypeptide theory.

5.14.2. TYPES OF GENES

- [1] Holandric Gene: The genes are present in the Y chromosome, helping in paternal transmission of characters.
- [2] Jumping Gene: The DNA sequences which can change positions within one chromosome or between chromosomes is known as transposons or jumping genes.
 - [3] Lethal Gene: The genes causing lethality in an organism.
 - [4] Onco Gene: The genes inducing neoplastic growth in an organism.
- [5] Overlapping Gene: The genes which are functional within large sized genes as in case of some viral gene.
- [6] Plasma Gene: The extra nuclear inheritance brought upon by the DNA present in the cytoplasmic organelles.
- [7] Pseudo-Gene: The part of the DNA not involved in transcription is known as Pseudo-Gene.
- [8] Split Gene: The entire DNA can be divided into functional sequences called exon and non-functional repetitive sequences called introns. This dual nature of the DNA has been termed as Split gene.

Division of labour within genes: Benzer (1955) identified five different types of genes on the basis of their functions. They are as follows:

- [a] Muton: The smallest sequence of DNA capable of undergoing mutation, which should at least have a pair of nitrogen bases.
 - [b] Recon: The smallest DNA segment which induces crossing over.
 - [c] Cistron: The functional DNA segment coding for a single polypeptide.
 - [d] Complon: The particular DNA segment coding for more than one polypeptide.
 - [e] Replicon: The DNA segment consisting of more than one complon.

5.15. Central Dogma and Mode of Transcription:

Central Dogma: Synthesis of m-RNA from DNA by transcription and synthesis of polypeptide from m-RNA is termed by translation is known as Central Dogma. Synthesis of DNA from RNA is found in cancer viruses and it is called reverse transcription.

- [A] Transcription: Definition: The transfer of genetic information from DNA to m-RNA is known as transcription,. Then RNA formed is not binding with the DNA with hydrogen bonds, so it separates easily and goes to the cytoplasm. There are four major steps of transcription.
- [1] Initiation of m-RNA synthesis: The m-RNA synthesis starts on the DNA at a particular region rich in A = T having the sequence TATAATG, commonly called TATA box. The sigma factor (σ) is helping as the recognition signal.
- [2] Elongation of m-RNA polynucleotide: The elongation of m-RNA takes place from 5' to 3' direction. The first nucleotide incorporated is always A or G. The elongation occurs at a speed of 30 nucleotide per second.
- [3] **Termination of m-RNA synthesis:** The termination of m-RNA synthesis occurs after recognition of the termination signal and it is helped by the **rho** factor. The termination occurs in a GC rich region in prokaryotes and AT rich region in eukaryotes.
- [4] Processing of m- RNA polynucleotide: The m-RNA polynucleotide is shortened by splicing off of the repetitive sequence. There is an attachment of a tail composed of multiple adenine and this is called polydenylation, which is helping in the transfer of m-RNA into the cytoplasm.
- [B] Translation: The m-RNA contains a particular sequence of nitrogen bases remaining in linear fashion.

5.16. DNA as the Genetic Material

Upto 1950, there was a controversy regarding the fact that among chromosomal protein and DNA, which one is the actual genetic material of an organism.

Then it was shown that genes are composed of DNA and prove they are actual genetic material of an organism. Later of course certain viruses were denoted, (e.g. cancer and AIDS virus) where RNA is the genetic material. There are some experiments that directly denote that DNA is the genetic material.

[1] Bacterial Transformation: In 1928, F. Griffith isolated two strains of bacteria, Diplococcus pneumoniae, one was rough walled (with pili on the wall) referred to as type IIR and the other one covered with an external slimy coat (formed of glucuronic acid) is smooth in nature and is referred to as type III S.

He did the following experiments:

- (i) Injected type II R to mice, the mice could survive because it destroyed the bacteria with its defence system, so the bacteria was considered to be avirulent in nature.
- (ii) Type III S was injected to the mice and it died of pneumonia, so the bacteria was considered to be virulent in nature.
- (iii) Type III S was heated at high temperature (121.6°C) and when the heat killed strains (HK) injected to mice, it was alive because there was no pneumonia.

(iv) The HK III S and II R were injected and the mice was dead. Virulent IIIS were recovered from the rat's dead body. Hence Griffith concluded that in presence of type III S (HK), the avirulent type II R is transformed to type III S. This is known as bacterial transformation or Griffith's effect.

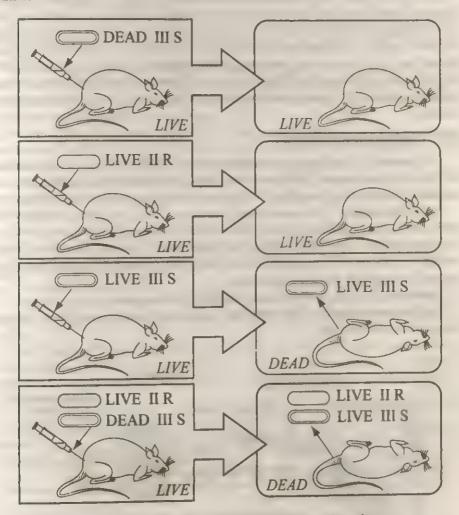


Fig. 5.17: Griffith's experiment on bacterial transformation

Griffith could not explain the actual cause of transformation, but later O.T. Avery, C.M. Mcleod and M.McCarthy in 1944 successfully separated the DNA from the rest of the cellular components by enzymatic means and showed that even then bacterial transformation from II R to III S was taking place in presence of the DNA of HK III S type. From this experiment it was concluded that DNA is the genetic material.

Similar property is also exhibited by other bacteria like Haemophilus influenzae; Bacillus subtilis.

[2] Viral Transduction:

A. Hershey and M. Chase (1952) used radio active isotopes P³² and S ³⁵ to prove that DNA is the genetic material. They grew the bacterium Escherichia coli in a medium containing P^{tr} and S^{tr} in the culture medium and these components got incorporated in the $E.\ coh$ cells. Later Γ_2 bacteriophage particles were allowed to invade these radioactive labelled bacteria. Subequently, the bacteriophage showed the labelling of P^{tr} in the DNA and S^{tr} in the protein capsid. These radioactive phage particles were separated from the bacteria by centrifugation and added to another set of bacteria grown in non-tadioactive medium. Later P^{tr} was recovered from the non-radioactive host bacterium, while S^{tr} remained in the medium. This suggested that the **phage DNA** had entered the host bacterium as **the true genetic material**, while S^{tr} remained in the capsid outside the bacterial cell. This experiment of **Hershey** and **Chase** was confirmed by **E.Rosenberg** (1971) and it was proved beyond any doubt that DNA is the genetic material.

5.17. Chromosome Material

- (i) **Chromatin**: It is the chromosomal material of eukaryotic cell. It is a complex of DNA, RNA and protein. The proteins are mostly historics but non-histories are also available. Chromatin can be classified into 2 major types on the basis of staining:
- [A] Euchromatin: The uncondensed chromatin during interphase is known as Euchromatin. It constitutes the major portion of the chromatin and is rich in DNA, so it is functional in nature. When stained with basic stam, it takes up light stain during Interphase because of its elongated nature and is deep stained during the divisional phases, because of its spirally coiled nature.

Functions: It controls all the major activities of chromosome.

[B] Heterochromatin: The condensed form of chromatin during Interphase is known as heterochromatin.

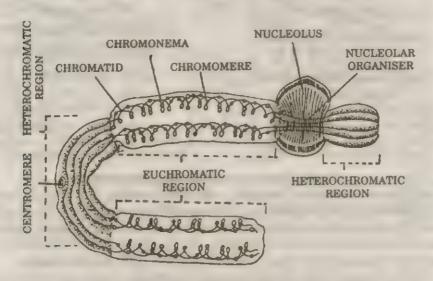


Fig. 5.18: Fuchromatic and Heterochromatic regions of a chromosome

Heitz (1928) first defined Hetrochromatin as condensed chromatin bodies forming the chromocentres or false nucleoli.

Darlington and La Cour (1965) reported that they are deep stained at Interphase but unstained during metaphase. They remain localized in a chromosome in the

nucleolus, centromere, telomeres or remaining interspersed with euchromatin regions. They exhibit differential staining at the same stage of cell division which is called heteropycnosis. It is composed of fibrils with a diameter of 250 V. They are genetically inert because mostly are formed of repetitive DNA sequences. They can be classified on the basis of their condensation:

[a] Constitutive heterochromatin: It is the permanently condensed heterochromatin in all cells. They are the most common type found near the centromere or telomere.

They contain repetitive DNA sequences and replicates late, not controlling any major function. Recently some polygenes have been isolated from here, which codes for ribosomal RNA e.g. 1/20th of salivary gland chromosome in diptera insects constitutes constitutive hetrochromatin.

[b] Facultative Heterochromatin: It remains condensed in some specific cells. It remains mactive in an entire chromosome to a his the dosage of some important genes in an organism, e.g. the second X Chrososome in numan teniale.

[c] Condensed Heterochromatin: Lewin (1974) introduced this type of heterochromatin to inidicate the deeply stanted and tightly coiled heterochromatin of

certain plants.

Functions: They help in the formation of thosomes and rRNA. They are involved in separation of chromosomes during cent division Greater amount of heterochromatin in an organism, may induce metabolic irrectalarity due to RNA synthesis (Brown, 1966).

Position Effect: When the euchromatin is adjacent to Heterochromatin, then there may be heterochromatinization of euchromatin by accident called Position effect.

Barr Body: The mactive second X chromosome in human female denoted by Murray Barr (1949). It is to prevent the double dosage of X chromosome in female (Dosage Compensation of Lyon). It is used to test the sex of individual and superfemale syndrome.

• Different between Enchromatin and Hetrochromatin :

Points of Difference	Euchromatin	Heterochromatin.
1. Condensation :	Condensed at interphase dispersed in divisional stages	Dispersed in interphase, condensed in divisional stage
2. Staining:	Takes up dark stain during interphase.	Remains light stained during interphase
3. Distribution:	Major portion of the chromosome.	Much less in compar on to heterochromatin
4. Position :	Centromerie and Intercalary in nature.	Distributed in the entire
5. Types:	Facultative and Constitutive	Carnothe danifol
6. Replication:	Late 5 phase	Highly settice
7 Genetic activity: 8 Repetitive nature:	Inactive Moderate to highly repetitive in nature.	Moderate to low repetitive nature.
9.DNA methylation:	Comparatively high	Comparatively low
10 Banding pattern :	C and G hands	Rtard,
11 Satellite DNA:	Slightly high	Comparatively less
12 Basepairs:	G C and A I may be equal or sometimes slightly enriched in A T base pairs	G/C base pairs

5.18. Human chromosome

The diploid number of chromosomes that is 2n = 46 was denoted by J.H. Tijo and A. Levan in 1956 from the fibroblasts of human embryos. Ford and Hamerton confirmed the observation by working with testicular material. Out of the 23 pairs of chromosomes, there are 22 pairs of autosomes and one pair of sex chromosome.

5.18.1. KARYOTYPE OF HUMAN CHROMOSOME

The karyotype of human chromosome is made from W.B.C. preparation of human venous blood. It was easily possible after Moorhead (1960) described the method to culture human lymphyocytes. The cells were made to divide by adding Phytohaemagglutinin and then division was arrested at the metaphase stage by adding colchicine. The preparation was stained in Giemsa technique and observed under high power microscope.

The karytope was based on

- [a] Shape of chromosome
- [b] Length of chromosome
- [c] Centromeric index
- [d] Proportion of the arms.

Accordingly, Patau (1960) divided human chromosome into 7 groups.

These groups are as follows:

Group	Homologous chrosmosome number	Size	Nature
A	1,2,3	Largest	Metacentric
B ' /	4,5	Large	Submetacentric
C	6,7,8,9,10,11,12	Medium	Submetacentric
	and X		
D	13, 14, 15	Medium	Acrocentric
E	16,17,18	Small	Submetacentric
			(16 is metacentric)
F	19.20	Small	Metacentric
G	21, 22, and Y	Smallest	Acrocentric

15.18.2 CHROMOSOME BANDING

The chromosomes after being stained with basic dyes show typical and interbanding patterens. These fluorescent dyes are mainly of 2 types — Quinacrine mustard and Giemsa. The main banding patterns are as follows:

- [1] 'Q' banding: The chromosomes stained with Quinacrine mustard shows this type of banding where the DNA is rich in adenine and thymine.
- [2] 'G' Banding: It is by using the Giemsa stain and it recognises the euchromatin, centromeric and intercalary heterochromatin.
 - [3] 'C' Banding: Mainly identifies the constitutive heterochromatın.
 - [4] 'R' Banding: These bands are in reverse pattern to that of Q and G banding.
 - [5] 'T' Banding: The bands identified by Feulgen stain.

[6] 'F' Banding: The bands identified by Feulgen stain.

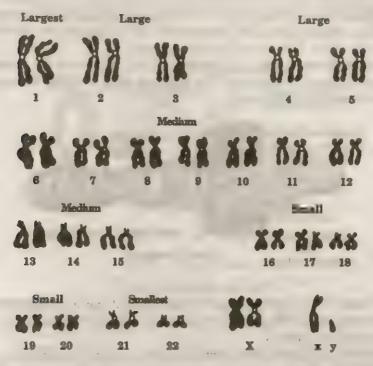


Fig. 5.19: Karyotype of Human Chromosomes

[7] 'N' Banding: The selective staining of the Nucleolus Organizers in the chromosomes pair 13,14, 15, 21 and 22.

5.19. DNA finger printing

The process of identifying a person by studying the nitrogen base sequence of the DNA is known as DNA fingers printing. In human, 90% of the DNA sequences are identical, only they differ in 10% of short fragments of DNA called junk DNA. It was developed by A. Jeffreys et al (1986) in the Leicester University, U.K.

5.19.1 TECHINQUE

The junk DNA fragments are isolated from the blood stain, hair-root and are amplified by polymerase chain raction (PCR technique). Amplified DNA fragments are blotted in nitrocellulose paper by Southern Blotting method. Then they are subjected to DNA hybridization with the specific known DNA probe prepared by cloning. This probe is radioactive in nature and the hybridized zone are developed on a X-ray plate. The dark bands appearing on the X-ray plate reveal the DNA finger-print. It is also called DNA profiling or DNA typing.

5.19.2 IMPORTANCE

These tests are widely used in forensic science, in denoting criminals (e.g. 'Dhanu' was detected by DNA fingerprint in Rajiv Gandhi assassination case). It is also used to solve paternity dispute case and rape cases. In India, these tests are effectively carried out by the Centre for Cellular and Molecular Biology (CCMB), Hyderabad.

5.20. Special type of chromosomes:

The chromosomes which are larger or smaller than the normal chromosomes of an organism are considered as special chromosomes of an organism are considered as special chromosomes. They are of the following types.

[A] Polytene Chromosome: E.C. Balbiani (1881) discovered this chromosome in the salivary gland of *Chironomous*. The name was given by Kollar because of the presence of multiple chromonemata.

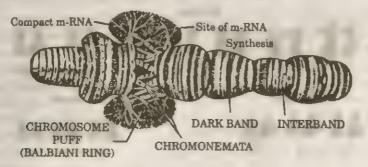


Fig. 5.20: Polytene Chromosome

Occurrence: They occur in the tissues of salivary gland, trachea, malpighian tubules of Diptera larva (insects). They are observed during interphase. They arise due to DNA replication even after mitosis.

Structure: The polytene chromosome after staining shows alternate light and dark bands all along their length. The dark bands are euchromatic in nature containing more

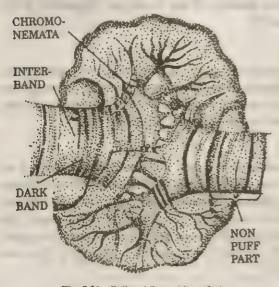


Fig. 5.21: Balbiani Ring (Magnified)

DNA and less RNA, whereas interband are heterochromatic in nature with less DNA and more RNA. They may be formed of upto 4000 units of chromatids formed of nucleoprotein fibres (500 Å). The dark band or interband has got some swollen regions called chromosome puffs, these are actually highly coiled chromatin fibres. They contain compact m-RNA and help in protein synthesis. There are some ring-like structures evaginating out of the polytene chrtomosome at certain areas of puffing called Balbiani rings. They have same function as puffs. The puffing of polytene

chromosome has got a definite role in moulting of insects.

[B] Lampbrush Chromosome: Flemming discovered the lampbrush chromosomes in amphibian oocytes in 1882. Ruckert (1892) described it in the oocytes of shark.

Occurrence: These chromosomes are observed in the diplotene stage of yolk-rich oocytes of fishes, amphibia, reptiles and birds. They are also present in the invertebrates but have slightly different appearance.

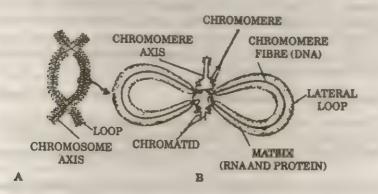


Fig. 5.22 : Lampbrush Chromosome

A—Lampbrush Chromosome B—Chromosome Loops

Structure: Each chromosome consists of a main axis and lateral loops. The axis is formed of four chromatids or two bivalent chromosomes. The lateral loops are formed by the chromonemata, which appear like a lampbrush. The loops consist of a main axis of DNA covered by RNA and protein (Miller and Beatty, 1969). These loops open out form the chromosome at the thin end and rewinds at the thick end. These chromosomes generally varies from 20 μ to 1000 μ during early prophase I, it is maximum, i.e. 5900 μ in Salamandar oocytes. Normally these chromosomes develope into lampbrush like appearance when RNA synthesis is intense, but these loops become thin when the synthesized RNA are transported away.

- [C] B-Chromosomes: These chromosomes are a special type of chromosomes which remain in monocotyledonous plants and insects in addition to normal autosomes and sex chromosomes. They are also called supernumerary chromosomes. They are smaller than autosomes and do not form synapses with them. They are smaller than autosomes and do not form synapses with them. They are derived from autosomes, where the euchromatin is lost, but centromere and heterochromatin are retained. Mostly there are two supernumerary chromosomes, commonly found in plants, only in Tradescantia edwardsiana there are five upernumerary chromosomes, Gibson (1970) denoted the base composition of DNA of B-chromosomes. They may cause deleterious effect in animals, but in plants they affect fertility when present in large amount.
- [D] L-Chromosomes: The L chromosomes or Limited chromosomes are constant in the individual species. They are found in Diptera insects, only in the germ cells. In both male and female, a pair of L chromosomes are denoted.
- [E] m-Chromosomes: They are also called minute chromosomes because they are smaller than 0.5μ. They are found in Bryophytes and Heteroptera insects. Upto 4-5 m-chromosomes may be present in a species. As because they are present in all individuals of a species, they are different from supernumerary chromosomes.
- [F] S and E Chromosomes: They are also called somatic and eliminated chromosomes. They are found in diptera insects. In both male and female, there are

48 Chromosomes in the germ cells. In female, the somatic cell contains only 12 somatic chromosomes and the rest 36 are eliminated, but in male, there are only 6 somatic chromosomes and rest 42 are eliminated.

[G] Mega Chromosomes: In some plants like tobacco hybrids, there are certain chromosomes, which are 15 times larger than normal chromosomes which are called mega chromosomes. They are heterochromatic and non-polytenic in nature. There may be upto 7 mega chromosomes present in a cell and appear in successive generations, though they are not transmitted through gametes, which indicates that the ability to produce these chromosomes is inheritable.

5.21. Significance of chromosome:

- [1] They control all the major biological and genetical activities of the cell.
- [2] They transmit the hereditary characters from generation to generation.
- [3] They contain the genetic material of DNA and control protein synthesis within a cell.
 - [4] They determine the morphological chracteristics of the different organisms.

5.22. Distinguish between:

some RNA viruses.

_		
[a]	Centrosome	Centromere
[2]	It is a cytoplasmic organelle of animal cell and lower plant call. Made up of lipo-protein. It consists of the centriole which divide at the onset of cell-division. It forms the spindle fibre in animal cell and help in the movement of lower plant cells.	 It is part of the chromosome visible during cell division. Made up of nucleoprotem. It consists of 4 centromeric chromomeres dividing at the time of anaphasic separation of chromosome. It helps in the attachment of spindle fibres to the chromosomes during anaphase.
[b]	.at Codon , remain	Anticodon
[1]	It is the sequence of nitrogen bases arranged in the sequence of three bases together on the m-RNA.	[1] The three nitrogen bases of the t-RNA.
[2]	They attract the anticodon of t-RNA.	[2] They help in the binding of respective amino acids.
[c]	Transcription	Translation
[1]	The process of synthesis of m-RNA from the DNA.	[1] The process of synthesis of polypeptide by m-RNA.
[2]	It takes place in the nucleus.	[2] It takes place in the cytoplasm.
[3]	The process is simple, direct and completed within short time.	[3] The process is complicated with the participation of t-RNA, ribosomes and other protein factors.
[4]	Reverse transcription is possible in	[4] Reverse translation is never possible.

[d] B. Chromosomes	Lampbrush Chromosomes
[1] Found mainly in plants.	[1] Found in oocytes of fishes, amphibia,
[2] Smaller than autosome.	reptiles and birds. [2] Very large in size.
[3] They have no specific structure.	[3] They have lampbrush-like appearance due to the formation of lateral loops.
[4] They mostly consist of hetero- chromatin and is genetically inert	[4] They contain a main axis of functional

5.23. Matters to recollect

- Chromosome was first coined by Waldeyer (1888).
- Chromosome is a condensed nucleoprotein thread-like particle with hereditary function formed from the nuclear reticulum during cell division.
- Genome represents the basic haploid set of chromosome.
- Autosomes determine somatic characters but sex chromosomes help in differentiation of sex.
- The Lampbrush chromosomes are largest whereas m-chromosomes are smallest.
- Centromere is a region in the chromosome where the sister chromotids are attached.
- Kinetochore is the central disc-like structure of the centromere where the microtubules are attached.
- Chromomeres are the beaded chromatin granules distributed all along the chromatid,
- distinct in the centromeric region.
- Telomere remains at the end of chromosomes providing non-sticky nature.
- The nucleolus organization region remain within the secondary constriction which form the nucleolus in the interphase nucleus.
- The satellite is a small heterochromatin projection beyond the terminal secondary constriction.
- Gene is a functional fragment of DNA nucleotide acting as the hereditary unit of chromosome.
- Chromosome contains 90% DNA with basic protein and 10% RNA with acidic protein.
- Heterochromatin remains condensed and euchromatin is uncondensed during interphase.
- The latest model for chromosome is the Nucleosome model consisting of histone core and linker DNA.
- The diagrammatic representation of chromosome of an individual is called karyotype, but the systemic study of homologus chromosomes according to decreasing order of size of chromosome is known as idiogram.
- The DNA is a double helix, mostly remaining as a right handed plectonemic coil formed of deoxyribose sugar, phosphoric acid and nitrogen bases (adenine, guanine, thymine and cytosine).
- The RNA is single stranded structure formed of ribose sugar, phosphoric acid and nitrogen bases (adenine, guanine, uracil and cytosine).

- The genes directly control the activity of enzymes or polypeptides.
- The operon is an aggregation of several genes having specific function.
- Nucleotide is composed of one deoxyribose phosphate unit (in DNA) or one ribose phosphate unit (in RNA) with purine or pyrimidine bases.
- Nucleoside is composed of one deoxyribose molecule (in DNA) or one ribose molecule (in RNA) with purine or pyrimidine.
- The DNA synthesizes m-RNA by transcription which goes to the cytoplasm, binds with t-RNA and ribosome and synthesizes the polypeptide by translation.
- The replication of DNA is always semi-conservative in nature.
- The daughter strands are produced by template synthesis on a RNA primer differentiated into leading strand and lagging strand.
- Human chromosomes are divided into seven major groups and they exihibit G and Q banding pattern.
- DNA finger printing is the study of DNA pattern used in the detection of individual identity.
- Polytene chromosomes are giant chromosomes of insects helping in gradual moulting of larva.
- Lampbrush chromosomes are very large bivalent chromosomes found in amphibian oocytes.
- B-chromosomes of an organims are excess heterochromatic chromosomes.
- Limited chromosomes are fixed in an organism.
- m-chromosomes are smallest in size.
- S and E chromosomes are both present in a germ cell, but E chromosomes are eliminated from the somatic cells.

5.24. Summary

Chromosomes are composed of nucleic acid and protein. It may be metacentric, submetacentric, acrocentric and telocentric depending upon the position of the centromere. The basic set of chromosomes in an individual gamete is called genome. All individual species have a definite number of chromosomes. Each chromosome consists of chromatids, primary constriction, secondary constriction, centromere, nucleolus organizer, telomere. The euchromatin and heterochromatins are identified as light and dark stained regions on the interphase chromosome. The chromosomes bear the hereditary units called genes, which are functional fragments of DNA. The DNA and RNA are composed of pentose sugar, phosphoric acid and nitrogen bases. The genes control the activities of enzymes indirectly and the polypeptides directly. A group of genes having specific function are together called as operon which can be swithched on and off by adding derepressor and aporepressor. The replication of DNA is semi-conservative in nature. The DNA synthesizes the m-RNA by transcription, which finally forms the polypeptide by translation. The polytene, Lampbrush, B-Chromosomes, L-Chromosome, m Chromosome, S and E Chromosomes are some of the special types of chromosomes having different structure and function.

5.25. Naming/Discovery/Discoverer

- [1] Karl Nageli (1842) observed rod-like structures in the nucleus of plant cells.
- [2] E. Strasburger (1875) reported formation of thread-like structures during cell division.
 - [3] W. Flemming (1878) introduced the term chromatin.
- [4] Benden and Bovery (1887) reported the number of these thread-like structures are constant for individual species.
 - [5] W. Waldeyer (1888) named these thread-like structures as chromosomes.
 - [6] Sutton (1902) proposed the theory of chromosomal basis of heredity.
 - [7] R. Feulgen (1914) demonstrated the Feulgen staining for DNA.
- [8] T. Morgan and H. Muller (1922) located 2000 genetic factors on the four chromosomes of *Drosophila*.
 - [9] F. Griffith (1928) denoted transformation in bacteria.
 - [10] Heitz (1935) and Kuwanda (1939) described the morphology of chromosomes.
- [11] G.W. Beadle and E.L. Tatum (1941) published the theory of one gene one enzyme based on biochemical genetics of *Neurospora*.
- [12] O.T. Avery; C.M. Mcleod and M. Mc Carthy (1944) examined the DNA of *Pneumococcus* bacteria and called it a genetic material.
- [13] A. Boivin, R. Vendrely and C. Vendrely (1948) showed that in a single organism, the total DNA present in the haploid set of chromosome is constant.
- [14] E. Chargaff (1950): Demonstrated that in the DNA molecule, the number of adenine-thymine base pairs is always equal to the guanine—cytosine base pairs.
 - [15] A. Hershey and M. Chase (1952) denoted transduction in bacteriophage.
- [16] J.D. Watson and F. H.C. Crick (1953) proposed the double helix model of DNA with the purine and pyrimidine bases attached by hydrogen bonds.
- [17] A. Gierer and G. Schramm (1956) showed that RNA was the genetic material for tobacco mosaic virus.
- [18] M. Meselson and F. W. Stahl (1957) proved in bacteria that DNA replication is semi-conservative in nature.
- [19] M. W. Nirenberg and J. W. Matthai (1961) cracked the messagenger RNA Code.
 - [20] F. Jacob and J. Monod (1961) proposed the operon concept.
- [21] K.A. Marker and F. Sanger (1964) proposed the structure of N-formyl methionyl-t-RNA and explained its role in initation of translation.
- [22] **Dupraw** (1965) proposed the folded fibre model of chromosome to denote the highly folded single DNA molecule wrapping the chromosomal protein.
- [23] R.W. Holley; H.G. Khorana and M. W. Nirenberg (1968) got Noble prize for deciphering the genetic code.
 - [24] S.H. Kim (1973) suggested the three dimensional L-shaped model of t-RNA.
- [25] R.D. Kornberg (1974) proposed the 'nucleosome model' of chromosome and the term nucleosome was coined by **P. Outdet** *etal* (1975)
 - [26] P.A. Sharp and R.J. Roberts (1977) discovered the split genes of Adenovirus.
 - [27] W. Gilbert (1978) denoted split gene as exon and intron.
 - [28] R.D. Plamiter and R.L.Brinter (1982) produced the split genes of Adenovirus.
- [29] K. Mullis (1985) discovered the Polymerase chain reaction (PCR) technique in Genetic Engineering using the enzyme Taq DNA polymerase.

[30] A. Jeffreys (1986) discovered the technique of DNA fingerprinting.

[31] J.W. Black; G.B. Elion and G.H. Hitching (1988) got Nobel prize for formulating DNA synthesis inhibitors like thioguanine useful in cancer chemotherapy.

[32] T. Cech and J. Altman (1989) awarded the Nobel Prize for explaning the enzymatic role of RNA molecules in the form of Ribozymes.

5.26. Answer to special questions:

- [1] What is the number of chromosomes in human spermatozoa? (J.E.E. 1996) Ans. The number of chromosomes in human spermatozoa is 23.
- [2] What is holokinetic chromosome?

 Ans. The other name for polycentric chromosome.
- [4] What is Somatic pairing?

 Ans. The phenomenon by which the chromatids after duplication during interphase do not separate from each other.
- [5] What is Endomitosis?

 Ans. Repeated division of the chromatid to form a polytene chromosome.
- Where from DNA derived its name? Who first described the double helix structure of DNA? (J.E.E.1997)

 Ans. DNA is derived from deoxyribose sugar and nucleic acid. DNA double helix was described by J.D. Watson and F.H.C. Crick in 1953.
- [7] Name the DNA nucleotide containing Adenine. (J.E.E. 1997)

 Ans. It is deoxyadenosine monophosphate (dAMP).
- [8] What is extra-nuclear DNA?

 Ans. The DNA present in the mitochondria and chloroplastid outside the nucleus is termed as extra-nuclear DNA.
- [9] Can DNA occur in the cytoplasm of eukaryotic cell? (J.E.E. 1997)
 Ans. DNA may be present in the cytoplasm of eukaryotic cell.
- [10] What is selfish DNA?

 Ans. The repetitive sequences of eukaryotic DNAs which do not take part on protein synthesis.
- [11] Where is r-RNA synthesized?

 Ans. The r-RNA is synthesized in the nucleolus.

 (J.E.E. 1987)
- [12] What is gene?

 Ans. The functional fragment of DNA with 500 to 2000 base pairs.
- [13] How many genes are there in human?

 Ans. There are about 1,00,000 genes present in the 46 chromosomes.
- [14] What is Lyon's hypothesis?

 Ans. The second X chromosome in human female become hetero-chromatinized and forms the barr body to prevent the double dosage of X chromosomes. It is also called dosage compensation.

en antiama . (Ans. 5.20)

[15] What is supernatant RNA? Ans. The other name for t-RNA.

What is nucleosome?

What is chromosome puff?

[3]

[16] What are nonsense codons? Ans. The codons like UAA, UAG and UGA, which do not code for any amino acid are known as nonsense codons.

[17] What is Satellite DNA? Ans. In eukatyotes, the sequence of nitrogen bases repeated 16-64 times in tandem, near the centromere of a chromosome.

[18] What is Central Dogma? Ans. Synthesis of m-RNA from DNA by transcription and polypeptide from m-RNA by translation is known as Central Dogma.

[19] What is Teminism? Ans. The synthesis of DNA from m-RNA by reverse transcription followed by the synthesis of m-RNA and protein by that DNA strand is known as Teminism. It was reported by Temin and Baltimore (1970) in Retro virus.

[20] What is initiating codon? Ans. The codon AUG coding for the amino acid methionine initiates the process of polypeptide synthesis and is known as initiating codon.

[21] What is Okazaki fragments Ans. The small fragments of DNA formed after the RNA primer on the lagging strand during replication of DNA is known as Okazaki fragments.

[22] Wat are the different genes present in an operon? Ans. Promoter gene, Operator gene, Regulator gene and Structural genes.

	EXERCISE	
• A.	Essay type or Long answer type:	14 5 6 2)
[1]	Describe the morphology of chromosome with proper diagram.	(Ans. 5.6.3)
[2]	Discuss the chamical structure of chromosome.	(Ans. 5.8)
[3]	The state of chromosome again ? Describe the morphological structure of chromosome w	ith the help of
10]	a sketch. Write the names of the different components of chromosome. Mention the function	ns on unificient
		(union state)
[4]	Mention only the structural parts of metaphase chromosome. Classify chromosomes	according to
Let	handle decembe each type with diagram	(Millar Dione)
[5]	the state of the banderd and diploid chromosome number: According to	o position of
(-)	centromere, how many shapes of chromosomes are there? What are nonlologous enrolled	SCHIES, HINE
	the state of the s	41121 5110111101
[6]	The Dallag Mantion the differences between RNA and DNA HOW does nives help in pro-	tein synthesis?
•	[3.8.£, £570] (A	ING. SOLL ! S CHAPPY
171	What is DNA? Describe the structure of DNA molecule. [Tripura H.S. 19	(Ans. 5.14)
[8]	Define gene. Describe the chemical nature of gene.	(Ans. 5.11)
[9]	What is RNA? Describe the chemical nature of RNA.	(Ans. 5.8)
[10]	How DNA replication occurs?	(Ans. 5.13)
[11]	What is nucleosome model?	(Ans. 5.8)
[12]	Characterise various forms of DNA	(Ans. 5.18)
[13]	What are the characteristic features of human chromosome? What are its various bands?	
[14]	What are the characteristic features by intrial characteristic features by intrinal characteristic features by intr	(Ans. 5.20)
	Chromosome?	, , , , , , , , , , , , , , , , , , , ,
• B S	Short Answer type:	
	What is centromere? Briefly describe the structure of centromere	(Ans. 5.6.3)
[1]	What is chromatid? Describe its structure.	(Ans. 5.6.3)
[2]	What is puclosome?	(Ans. 5.13)

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	A C C C C C C C C C C C C C C C C C C C	(Ans. 5.11)
[5]	What are the four bases of RNA?	[J.E.E. 1988] (Ans. 5.11)
[6]	Where RNA is synthesized?	(Ans. 5.5)
[7]	What is Autosome?	(Ans. 5.6.2)
[8]	What is Idiogram? Name the organisms having largest and smallest chromosome number.	(Ans. 5.4.1)
[9]	Why DNA replication is semi-conservative?	(Ans. 5.8)
[10]	Why DNA replication is semi-conscivative:	(Ans. 5.15)
[11]	How transcription occurs? Give the salient features of DNA double helix following Watson and Crick.	(Ans. 5.8)
[12]	What are supernumerary chromosomes?	(Ans. 5.20)
[13]	What are the various types of RNA found in an eukaryotic cell?	(Ans. 5.11)
[14]		(
●C.	Specific answer type:	
[1]	Where centromere is situated?	(Ans. 5.6.3)
[2]	What is genome?	(Ans. 15.4)
[3]	What is telocentric chromosome?	(Ans. 5.6.3)
[4]	What is Sat-Chromosome?	(Ans. 5.6.3)
[5]	What is paranemic coil?	(Ans. 5.6.3)
[6]	What is chromomere?	(Ans. 5.6.3)
[7]	What is primary constriction?	(Ans. 5.6.3)
[8]	What is plectonemic coil?	(Ans. 5.6.3)
[9]	What is secondary constriction?	(Ans. 5.6.3)
[10]	Which type of DNA is a left handed coil?	(Ans. 5.8)
[11]	Mention from the list below, which are not present in DNA: (i) Adening	
	(iv) Cytosine (v) Uracil (vi) Thymine	[J.E.E. 1993] (Ans. 5.8)
[12]	What are Balbiani Rings?	(Ans. 5.20)
[13]	Name the components of nucleosome octamer.	(Ans. 5.13)
[14]	What is Typtophan Operon?	(Ans. 5.14)
[15]	What is Unineme theory?	(Ans. 5.13)
[16]	What is solenoid?	(Ans. 15.13)
[17]	Name the nitrogenous bases present in RNA.	(Ans. 5.11)
• 1	D. Distinguish between :	
		(Ans. 5.6.3)
[1]	Chromonema and Chromomere.	(Ans. 5.6.3) (Ans. 5.6.3)
[1] [2]	Chromonema and Chromomere. Chromosome and Chromatid.	(Ans. 5.6.3)
[1] [2] [3]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere.	(Ans. 5.6.3) (Ans. 5.6.3)
[1] [2] [3] [4]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8)
[1] [2] [3] [4] [5]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17)
[1] [2] [3] [4] [5] [6]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3)
[1] [2] [3] [4] [5] [6]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17)
[1] [2] [3] [4] [5] [6] [7] [8]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3)
[1] [2] [3] [4] [5] [6] [7] [8] [9]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8)
[1] [2] [3] [4] [5] [6] [7] [8]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11)
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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding. Codon and Anticodon.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.18.2) (Ans. 5.22)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.18.2) (Ans. 5.22) (Ans. 5.22)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding. Codon and Anticodon.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.18.2) (Ans. 5.22)
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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] •E. 5	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding. Codon and Anticodon. Transcription and Translation. B-chromosome and Lampbrush Chromosome. Short Notes: Metacentric Chromosome	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.18.2) (Ans. 5.18.2) (Ans. 5.22) (Ans. 5.22) (Ans. 5.22) (Ans. 5.23)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] •E. S	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding. Codon and Anticodon. Transcription and Translation. B-chromosome and Lampbrush Chromosome. Short Notes: Metacentric Chromosome Centromere	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.18.2) (Ans. 5.22) (Ans. 5.22) (Ans. 5.22) (Ans. 5.23)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] •E. \$ {1} [2] [3]	Chromonema and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding. Codon and Anticodon. Transcription and Translation. B-chromosome and Lampbrush Chromosome. Short Notes: Metacentric Chromosome Centromere Nucleosome	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.18.2) (Ans. 5.18.2) (Ans. 5.22) (Ans. 5.22) (Ans. 5.23) (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.6.3)
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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] • E. S [1] [2] [3] [4] [5] [6] [7]	Chromosome and Chromomere. Chromosome and Chromatid. Chromomere and Centromere. DNA and RNA. Euchromatin and Heterochromatin. Primary Constriction and Secondary Constriction. Paranemic and plectonemic coiling. B-DNA and Z-DNA. Purine and Pyrimidine. m-RNA and r-RNA. Jumping Gene and Holandric Gene. Pseudo gene and Split gene. Q and G Banding. Codon and Anticodon. Transcription and Translation. B-chromosome and Lampbrush Chromosome. Short Notes: Metacentric Chromosome Centromere Nucleosome Polytene Chromosome R.N.A. D.N.A. D.N.A. D.N.A. D.N.A. Finger printing.	(Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.17) [J.E.E. 1987] (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.8) (Ans. 5.8) (Ans. 5.11) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.14.2) (Ans. 5.12.2) (Ans. 5.22) (Ans. 5.22) (Ans. 5.22) (Ans. 5.22) (Ans. 5.22) (Ans. 5.22) (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.6.3) (Ans. 5.13) (Ans. 5.22) (Ans. 5.11) (Ans. 5.11) (Ans. 5.11)
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113]	Lac Operon	(Ans. 5.14)
[14]	Selfish Gene	(Aps. 5.8)
115	Okazaki fragments	(Ans. 5.8
[16]	Constitutive Heterochromatin	(Ans. 5.17
oF.	Put ✓ Mark or Correct Statement :	
	The number of chromosomes in a genome is dipiloid haploid polyploid	
[1]	The head like structure of chromosome is called Chromomere Centromere Kinetochote	
[2]	Chromosome threads are called - chromonemata Chromatids DNA libre	
[4]	The region of centromere is called - Telomere - Chromomere Primary constriction	
[5]	The left handed DNA is - A-DNA/B-DNA/C-DNA/Z-DNA.	
[6]	The initiating Codon is UAG/UAA/UAC/AUG.	
171	Reverse transcription occures in - DNA virus/RNA virus lungi bacteria	
[8]	The longest RNA is - m-RNA/r-RNA/t-RNA/hn-RNA.	
[9]	The distance between two base pairs of DNA is - 2.4 \$\lambda 3.4\$\lambda 6.4\$\lambda.	
[10]	The Euchromatin is - stable / heteropycnotic/repetitive.	
●G.	Fill up the blanks with correct words :	
[1]	F Banding is brought upon by —— stain.	
[2]	The detection of criminal is brought upon by ———————————————————————————————————	
[3]	is induced by Colchicine.	
[4]	Prophase and metaphase is joined by ——.	
5	and are the two stages of protein synthesis.	
[6]	is the initiaing codon.	
[7]	Mega chromosomes are found in — hybrids.	
[8]		
[9]	- is a facultative heterochromatin.	
[10]	Put / mark on Yes or No for correct statements :	
	Mucor hemialis has the lowest chromosome number — Yes / No	
[1]	Ascaris megalocephala has the highest chromosome number - Yes - No	
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Cell Division

Topics Discussed: Introduction, Definition, Types of cell division, Amitotic cell division, Mitotic process in plant cell, Cell cycles, Types of cell cycle, Meiosis, Types of meiotic division, Meiotic process in plant cell, 1st Meiotic division, its substages, Leptotene, Zygotene, Pachytene (Crossing over), Diplotene (Chiasma formation). Diakinesis, Metaphase-I, Anaphase-I, Telophase-I, Cytokinesis, Prophase-II, Metaphase - II, Anaphase-II, Telophase-II, Cytokinesis, Meiotic process in animal cell. Significance of Meiosis, Main differences between Mitosis and Meiosis, Abnormal cell growth.

6.1. Introduction

The life of an organism start from a single cell, which divides and redivides to form multicellular organism, which ultamately produces an embryo or larva. The embryo or larva ultimately develop into adult organism via controlled cell division and differentiation. Cell division was discovered separtely by Von Mohl and Virchow in 1850. Hofmeister in the same year observed the division of one nucleus into daughter nuclei followed by the division of the cytoplasm. Cell division is considered as the fundamental characteristic of an organism, by virtue of which an organism increases in size. But immediately before cell division, the cell shows maximum anabolism and accumulation of cytoplasm. It is responsible for the continuity of life processes. It is mainly of two types, mitosis occurring in the somatic cells was denoted by Flemming in 1879 and meiosis, occurring in the germ cells was denoted by Moore and Framer is 1905. The nerve cell and matured RBC do not divide. The gametes are formed after meiosis but after attaining maturity, they do not divide.

6.2. Causes of cell division

- 1. Increase in the rate of metabolism induces auxetic growth (increase in volume of cytoplasm), which induces cell division and initiates multiplicative growth.
- 2. The doubling of DNA within a cell initiates nuclear division and ultimately resulting in the division of cytoplasm.
- 2. Damage or wound in the body of an organism causes increase in the rate of cell division for the purpose of healing of wound.

6.3. Importance

- 1. Production of new individual through reproduction.
- 2. Regeneration of damaged tissue.
- 3. To initiate growth and differentiation.
- 4. Development of different organs (organogenesis).
- 5. Modification in organs causing adaptation and permanent changes in adaptative features will induce evolution.

6.4. Definition of cell division

Cell Division is a fundamental and an active biological process by which a cell produces its own replica having similar structural and physiological properties and brings upon continuity of life.

6.5. Types of cell division

There are three principal types of cell divison which are as follows:

- 1. Amitosis or Direct Cell Division.
- 2. Mitosis or Indirect Cell Division.
- 3. Meiosis or Reductional Division.

6.5.1. AMITOSIS OR DIRECT CELL DIVISION

(Greek. A = no; mitos = thread) Term coined by Remark, 1840)

[A] Definition: The cell division showing simple nuclear cleavage without the formation of spindle fibres is known as Amitosis or Direct cell division.

[B] Occurrence: It is the major means of reproduction in bacteria, unicellular protozoa and unicellular fungi like yeast. It is also the multiplication process in vertebrate foetal membranes.

[C] Process: The process of Amitosis involves the following steps:

- 1. The cell is enlarged due to auxetic growth.
- The nucleus is enlarged and ultimately forms a dumbellshaped structure with the appearance of a median constriction.
- Two constrictions appear on the median part of the cell membrane.
- 4. The constrictions of the nucleus gradually grow

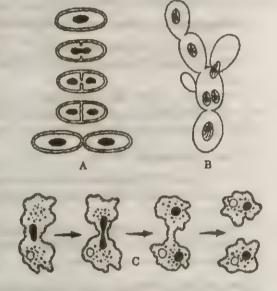


Fig. 6.1: Armtosis A-Bacteria, B-Yeast, C-Amoeba.

nucleus gradually grow deeper and divides the nucleus into two daughter nuclei without the formation of any spindle fibre.

5. The invaginations of the cell also move inwards and the parent cell is divided into two equal sized daughter cells.

[D] Advantage: 1. The division is completed within a short time.

2. It is the major means of reproduction in lower organisms like yeast, bacteria etc.

[E] Disadvantage: 1. There is no possibility of genetic recombination.

2. There is a possibility of expression of unwanted recessive genes.

6.5.2. MITOSIS OR INDIRECT CELL DIVISION (ONLY CELL CYCLE & INTERPHASE)

(Greek: mitos = thread)

[A] Introduction: The process of mitosis was first observed, described and named by W. Flemming (1879) in Salamander. Schleicher (1878) coined the term karyokinesis for nuclear division and Schneider (1879) described the various stages of mitosis in details. Cockraum and Mac Canley (1960) explained the biochemical

aspect of the process. Initially mitosis and karyokinesis were considered to be the same and cytokinesis (division of the cytoplasm) was a separate process. But later both karyokinesis and cytokinesis were considered as the two phases of mitosis. Mitosis takes place in the somatic cells of higher organisms. The daughter cells formed due to mitosis are identical in all respect to the parent cell, specially with respect to that of the number of chromosomes and hence it is called **Equational** division. The daughter nuclei are not formed directly from the parent nucleus but via the formation of chromosomes hence it is also called **Indirect** cell division.

[B] Definition: The cell division in which the the parent cell divides once giving rise to two identical daughter cells with same chromosome number with similar forms and characteristic feature is called mitosis.

[C] Occurrence: Mitosis occurs in the following cases:

- 1. In the somatic cells of all eukaryotes.
- 2. In the meristematic tissuses of plants *i.e.* radical, plumule, leaf primordia, growing buds *etc.*
- 3. In the lower animals during regenerative growth.
- 4. In the damaged plant parts for the purpose of healing of wounds.
- 5. In the development and differentiation of embryos.

[D] Factors inducing Mitosis:

- 1. Greater amount of cytoplasm in comparison to that of the nucleus
- 2. The increase in the metabolic processes which liberate more energy in the form of ATP molecules.
- 3. The increase in the amount of RNA in comparison to DNA.
- 4. Synthesis of specific proteins required during mitosis.
- 5. Availability of adequate substrate.
- [E] Mechanism of Mitosis: It is a process in which the chromosomes of the parent nucleus are distributed equally into the two daughter cells. The entire process consists of two major phases:
- [a] Karyokinesis (Greek, Karyon = Nucleus; Kinesis = movement) The division of the nucleus.
- [b] Cytokinesis: (Kitos = cell)— The division of the cytoplasm. In plant cell, cytokinesis occurs after the completion of karyokinesis but in animal cells, it occurs simultaneously with karyokinesis.

6.5.3. MITOTIC CYCLE OR CELL CYCLE:

It is the entire sequence of events happening from the end of one nuclear division to the beginning of the next.

Howard and **Pele** (1953) denoted four main phases of cell cycle G_1 , S, G_2 and M phases. The G_1 S, G_2 constitute the interphase but the M phase includes the prophase, prometaphase, metaphase, anaphase and telophase.

Albert et al (1989) denoted three major cycles of the cell cycle. [a] Chromosomal cycle: DNA synthesis alternating with mitosis, i.e. the DNA undergoes replication before they are actually separated. [b] Cytoplasmic cycle: The cell growth alternates

with cytokinesis, i.e. the components of the cytoplasm is duplicated before they are

actually divided. [c] Centrosome cycle: The centrosome duplicates prior to the mitotic division.

[2] Time taken for Mitotic Cell Division:

When the different phases of Mitosis are considered, in every organism, maximum time is necessary for the interphase and little time is needed for the rest of the cell division. This is because, the cell takes up all sorts of preparation for division during interphase. As for example in mammals, out of the 18 hrs. of cell division. 17 hrs. are taken up by the interphase, while only 1 hr. is for the rest of the division. The major stages of mitotic cell cycle and their duration is given below:

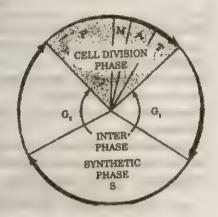


Fig. 6.2: Mitotic Cycle

Parts of cell	Phases	Description of phases	Duration in hours			
Cycle		Vicia fal		Mouse liver cells	Human Hela cells	
Interphase	G,	Pre-DNA-synthesis phase	12	12	12	
	S	DNA - synthesis phase	6	6-8	10	
	G,	Post DNA synthesis phase	12	3;-4	3	
Mitosis .	М	Mitotic phase	1	. 21	1	

Even the different subphase of mitotic phase also vary in their duration in different types pf cells of plants and animals. The table below indicate the duration of M phase in various organisms:

Organism	Duration in minutes				
& Type of Tissue	M. Phase	Prophase	Metaphase	Anaphase	Telophase
[1] Mouse spleen	43	21	13	5	4
[2] Grasshopper neuro- blasts	181	102	13	9,	57
[3] Sea urchin embryo	. 66	19	17	12	18
[4] Chicken mesenchyme cells in tissue culture	37.6-57.6	30.6		3-7_	2-10
[5] Pea root tip	109.8 1372	78	14.4	4.2	₹ 13.2
[6] Pea endosperm	182	40	20	12	110
[7] Onion root tip , ,	83.7	71	6.5	2.4	3.8

REVISION

Promitosis: Incomplete mitosis without division of the nuclear membrane.

Amitosis: Direct division of the nucleus involving cleavage of the protoplasm without spindle formation.

Mitosis or Eumitosis: Indirect nuclear division with spindle formation having karyokinesis and cytokinesis.

Endomitosis: Reduplication of chromatids within intact nucleus forming polytene chromosomes.

Crypto-mitosis: Chromosomes are formed during nuclear division but they are not arranged at the equatorial plane.

Paramitosis: Chromosomes do not undergo coiling during nuclear division.

6.5.4 IMPORTANCE OF INTERPHASE.

Definition: Interphase is a stage between two mitotic cycles in an eukaryotic cell, during which various physical and chemical changes for the preparation of cell division takes place.

It is the longest period of cell division and also called Intermitotic phase. The chromosomes appear as long and thin and forms diffused chromatin net. It is less visible due to highly hydrated condition.

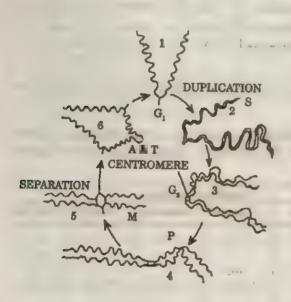


Fig. 6.3: Condensation & division of chromatids

Sub Division:—Interphase is divided into 3 subphases (Howard and Pele 1953).

- [1] Post-mitotic Gap phase (G₁ phase): It occupies 30-50% of the cell cycle and being the early stage of interphase, is also called the first growth phase. It shows the following events.
- (i) RNA and various regulatory proteins are synthesized.
- (ii) Enzymes required for DNA synthesis like DNA polymerase are synthesized.
- (iii) No synthesis of DNA takes place.
- (iv) Accumulation of tubulin occurs which causes elongation of the nucleus (Maclean and Hall, 1987).

 G_0 phase: In terminally differentiated somatic cells like neurone and muscle cells which cannot divide, the arrested G_1 phase is known as G_0 phase.

[2] Synthetic phase (S-phsae): It constitutes 35-45% of the cell cycle. It is the mid-interphase stage in which all the major metabolic activities of dividing cell takes place. The events are as follows:

- (i) DNA is synthesized.
- (ii) Volume of the nucleus becomes double due to DNA replication.

(iii) Histone proteins are sythesized.

- (iv) The single chromatid of the chromosome gets duplicated to form two identical chromatids.
- [3] Premitotic gap phase (G₂ phase): It constitutes 10-20% of cell cycle and also referred to as the second growth phase and actually is the gap between S phase and prophase. The major events include :-
 - (i) Synthesis of specific RNA and protein.
 - (ii) Stopping of DNA synthesis.
 - Major Characteristics of Interphase :
- (i) The replication of DNA and chromatid, thus the single chromatid (monad) becomes double (dyad).
 - (ii) Nuclear membrane remains intact and distinct.
- (iii) Nucleolus enlarges due to accumuation of RNA and ribosomal protein.
- (iv) Synthesis of energy rich ATP molecules and microtubules take place, which act as precursor of spindle fibres.
- (v) In general, the cell inreases in size due to accumulation of cytoplasm.
- (vi) In animal cell, a new centrosome is formed from the existing one with a pair of centroles placed at right angles to each other. So there are two pairs of centrioles placed at right angles to each other. So there are two pairs of centrioles within the cell.

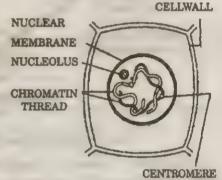


Fig. 6.4: Interphase Stage

- (vii) The thin and elongated chromtin threads of the chromatin network appear diffused and less visible due to highly hydrated condition.
- (viii) In animal cells, the net membrane biosynthesis increases and it remains stored at the cell surface in the form of blebs which help the cell to divide.

REVISION

 G_0 - phase - Arrested G_1 phase of non-dividing cells like neurone.

G. - Phase - The period of interval between telophase and S-phase.

G₂-phase - The period of interval between S-phase and prophase

S-phase - DNA synthetic phase of interphase.

Interphase - The period of interval between two cell divisions.

6.5.5 MEIOSIS OR REDUCTION DIVISION

(Gr. Meioum = to reduce)

[A] Introduction: The reduction in chromosome number during cell division was first reported by Van Beneden (1883). Bovery (1887) described the process of chromosome reduction in the gonads of Ascaris. J.B. Farmer (1905) named this process of cell division as meiosis. In this process, the chromosome actually divides only once but the cell divides twice. There are two separate divisions in the first case,

the chromosome number is reduced from **diploid** (2n) to **haploid** (n), while the second division just resembles a mitotic division. So the end products of meiosis always include four cells with haploid number of chromosomes, commonly reffered to as gametes. By reducing the chromosome number from diploid to haploid, the chromosome number is maintained in a particular species generation after generation.

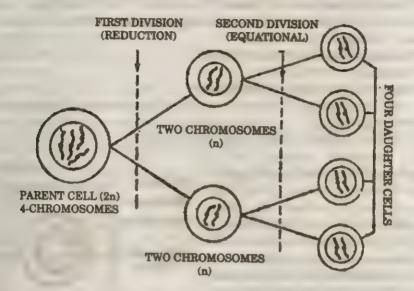
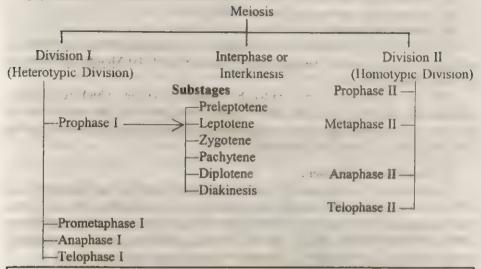


Fig. 6.5: Diagrammatic representation of Meiotic cell division.

- [B] Definition: Meiosis is a complex cell division process in which the diploid number of chromosome of the mother cell is reduced to haploid number of chromosomes in the four daughter cells.
- [C] Occurrence: It takes place in the eukaryotic diploid germ cells of the sex organs of plants and animals. These cells are called **meiocytes**. The meiocytes of plants are called **sporocytes** (**microsporocytes** in male plant and **megasporocytes** in female plant). In animals, the meiocytes of the gonads are called gonocytes, which may be spermatocytes in male and oocytes in female.
- [D] Types of Meiotic Division: Meiosis can be classified into three types on the basis of the type of cell, where it takes place:
- [1] Zygotic or Initial Meiosis: The process of meiosis that takes place immediately after the formation of zygote by syngamy, e.g. in lower plants like diatoms and certain fungi and some sporozoan animals.
- [2] Gametic or Terminal Meiosis: The meiotic process occurring at the time of gamete formation (spermatogenesis and oogenesis). e.g. lower plants and higher animals.
- [3] Sporic or Intermediary Meiosis: The meiotic process occuring at the time of spore formation in lower plants as well as flowering plants by microsporogenesis or megasporogenesis.

[E] Outlines of Meiosis:



REVISION

- [1] Cytokinesis Cleavage and division of cytoplasm.
- [2] Meiocyte Any cell undergoing meiotic division.
- [3] Zygotic Meiosis Meiosis taking place in the zygote immediately after fertilization.
- [4] Gametic Meiosis Meiosis occuring before the formation of gametes.
- [5] Sporic Meiosis Meiosis occuring before spore formation.

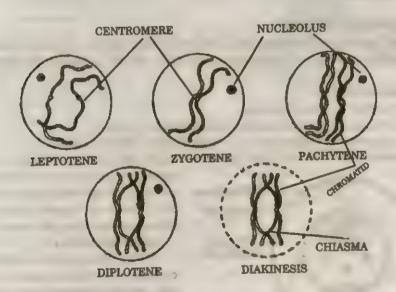


Fig. 6.6 : Substages of Miotic Prophase I , Leptotene, Zygotene, Pachytene, Diplotene, Diakinesis

[F] Factors inducing Meiosis:

- [1] Completion of vegetative growth.
- [2] Maturity of sex organs.

- [3] Disbalance of nucleic acids and certain hormones.
- [4] Increase in the amount of DNA and RNA.

[G] Process of Meiosis:

The process of meiotic cell division consists of two complete divisions of a diploid cell producing four haploid daughter cells. These are the (I) 1st Meiotic division and [II] 2nd Meiotic division.

The first meiotic division is called **heterotypic** division, which reduces the chromosome number from diploid into two haploid daughter cells. The second meiotic division is called **homotypic** division (**equational** division) as it produces four haploid cells from the two haploid parental cells.

[1] First Meiotic Division:

The process of meiosis actually starts in the interphase like that of mitosis and DNA duplication also takes place at the pre-meiotic 'S' phase. But at the 'G₂' phase, there are some decisive changes that direct the cell towards meiosis (Stern and Hotta; 1969). The first meiotic division has the following divisional stages: prophase-I, prometaphase-I, metaphase-I, anaphase-I, telophase-I and cytokinesis-I.

- [A] Prophase I: The meiotic prophase—I division is very important from cytological point of view and is the longest of all meiotic stages, which includes six substages, viz.
 - [1] Preleptotene or preleptonema
 - [2] Leptotene or leptonema
 - [3] Zygotene or zygonema
 - [4] Pachytene or pachynema
 - [5] Diplotene or diplonema and
 - [6] Diakinesis

Description of Substages:

[1] Preleptotene or Preleptonema: (Gr. Pro = before, leptas = thin, nema = thread)

Definition: The short stage before Leptotene when the uncoiling of chromatin starts.

Important events:

- [i] Decoiling of chromatin starts.
- [ii] Chromosomes began to appear as slender thin structures.
- [2] Leptotene or Leptonema: (Gr. Leptas = thin; nema = thread)

Definition: The chromosomes appear as single thread like structures bearing chromomeres. Leptotene is the first

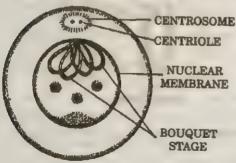


Fig. 6.7: Polarised stage (Bouquet Stage)

chromomeres. Leptotene is the first visible step. The meiocytes together with their nuclei appear longer and prominent than the neighbouring cells.

Important Events:

- [i] Nucleus becomes dehydrated, chromatin network loosens to form thin, uncoiled, slender chromosomes.
- [ii] Chromosomes have a definite configuration and their granular chromomeres are arranged at irregular intervals along their length.

[iii] In some plant cells, the chromosomes clump at one side of the nucleus, which is called syngenesis (synaptic knot).

[iv] In animal cells, the **bouquet stage** or **polarised stage** occur due to specific orientation of chromosomes in such a way that their converged ends form multiple loops of chromosomes on one side of the nucleus.

[v] In animal cells, the divided centrioles gradually move towards the two opposite

poles, 180° apart.

[vi] On reaching the two opposite poles, each centriole duplicates into two but remain within the single diplosome.

[3] Zygotene or Zygonema: (Zygon = adjoining) Definition: A stage in which pairing of homologous chromosomes and farmation of synaptonemal complex takes place.

Importent events:

- [i] Homologous chromosomes pair lengthwise by the phenomenon of synapsis (Gr. Syn. ≡ together; apsis ≡ loop) which takes place from chromomere to chromomere. The pairing takes place in a zipper like fashion and the paired chromosome is known as Bivalent chromosome.
- [ii] The process of synapsis starts at one or more points along the length of the chromosome. Accordingly, synapsis are of the following types:
- [a] Proterminal synapsis: When the synapsis starts from the terminal DIPLOTENE portion of a chromosome and continues towards the centromere.
- [b] **Procentric synapsis:** When the synapsis starts from the centromere and progresses towards the ends.
- [c] Intermediate synapsis: When

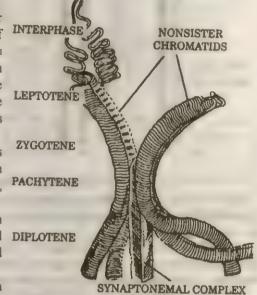


Fig. 6.8: Synaptonemal complex

the synapsis is oriented from any intermediate point of the homologous chromosomes.

[d] Localized or Random synapsis: When the synapsis occurs at various points

on the homologous chromosome.

[iii] During synapsis, an axial differentiation occurs in between the chromosome, which is in the form of a 0.2 µm protein band and it is termed as Synaptonemal complex (S.C.) The paired chromosome lie on either side of the complex. The S.C. stabilizes the homologous chromosomes and facilitates crossing over or recombination. It does not occur in those organisms where crossing over does not take place like male Drosophila (Burns and Bottino '89)

[iv] The shortening and thickening of the chromosomes and the nucleolus is still

visible.

[4] Pachytene or Pachynema: (Gr. Pachus = thick). Definition: The stage in

which crossing over and recombination of chromosome parts or genes between homologous chromosomes takes place.

Important events:

(i) The bivalent chromosomes become more prominent due to continuous thickening and shortening but they may remain in spirally twisted condition.

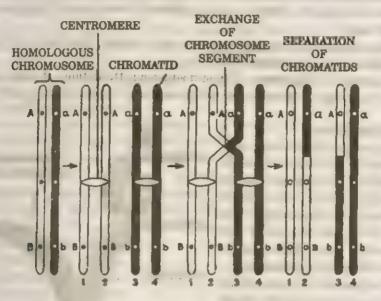


Fig. 6.9: Chiasma formation and Crossing over

- (ii) At the mid-pachytene stage, each of the homologous chromosomes cleaves longitudinally except at the centromeric region. Chromatids of the same chromosome are called sister chromatids.
- (iii) The four-chromatid condition of a bivalent is known as tetrad. (Althrough DNA replication occurs during S-stage of Interphase, yet it is not revealed until the ceasation of attraction between the two homologous chromosomes).
- (iv) Even at this stage, the chromosomes of a bivalent may remain in interwined condition.
 - (v) The crossing over (C.O) takes place at this stage.

Definition: Crossing over is a biological process of exchange of the corresponding parts of homologous chromosomes. The various changes during C.O are as follows:

- (a) An internal strain develops within the bivalent due to the coiling of homologous chromosomes.
 - (b) A transverse break appear at the same level of homologous chromatids.
- (c) The breaks are followed by the interchange of non-sister chromatid segments of homologous chromosomes.
- (d) Finally the union of interchanged segments take place. According to Stern and Hotta (1969) the breaking of chromatid arm is due to the action of endonuclease enzyme, while the union of chromatids arm takes place due to the action of ligase enzyme. Crossing over thus can be accompanied by DNA synthesis, which is used for repairing of chromatid arm but C.O. always involves exchange of a group of genes.

(vi) The nucleolus still remain attached with the nucleolar organisation region of a particular chromosome.

[5] Diplotene or Diplonema: (Gr. Diplo = Double; Name = thread)

Definition: The stage of meiosis in which the non-sister of homologous chromosomes touch each other followed by their separation.

Important events:

(i) The separation of paired homologous chromosomes (desynapsis) is initiated. But it is not completed because the

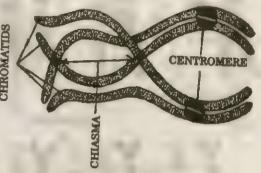


Fig. 6.10: Formation of Chiasma

chromosomes are held together at one or more points at thich C.O. has taken place. These points of attachment of homologous chromosomes are called **chiasmata** (sing. **chiasma**).

Chiasma: Definition: It is a cross like-configuration due to the attachment of non-sister chromatids of a bivalent, originated as a result of crossing over.

Chiasma is the morphological expression of crossing over. The formation of one chiasma at the diplotene stage results in the formation of a cross-like configuration of the bivalent. The formation of two chiasmata results in the formation of a ring while due to multiple chiasmata, the bivalent forms a series of loops.

Types of Chiasmata:

- (a) Terminal Chiasmata formed at the ends of chromosome.
- (b) Interstitial Chiasmata formed along the length of the chromosome.
- (ii) The chromosomes become more shorter, thicker and the nucleolus is less distinct.
- (iii) The terminal chiasmata slip off from the ends of chromatids by the process of terminalization and its place is taken up by interstitual chiasmata.
- (iv) The member of chiasmata gradually decreases and the process of terminalization is continued (up to the next phase).
 - (v) The chromatids show some amount of infolding and RNA synthesis.
- (vi) At the point of chiasma the bivalent arm begins to rotate (180° for one chiasma in short chromosomes forming a cross and 90° by more chiasmata in long chromosomes forming a loop).

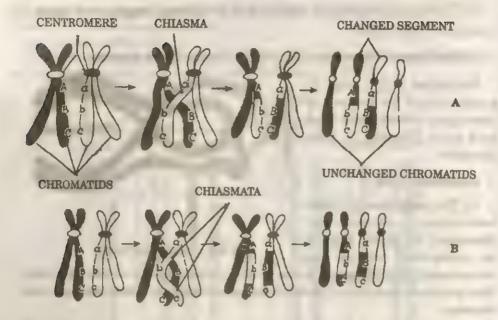


Fig. 6.11: Crossing over [A] At one point, [B] At two points

[6] Diakinesis: Definition: The last sub-stage of meiotic prophase I, in which reduction in number of chiasmata take place.

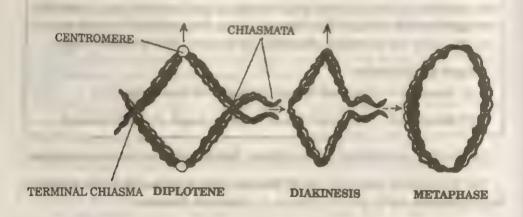


Fig. 6.12: Terminalization of chiasma

Important events:

- (i) Nucleolus gets detached from the nucleolus organiser of a particular chromosome and it ultimately disappears.
 - (ii) Bivalents become more contracted.
 - (iii) Terminalization and rotation continues.
 - (iv) At the end of this stage the nuclear membrane disappears.

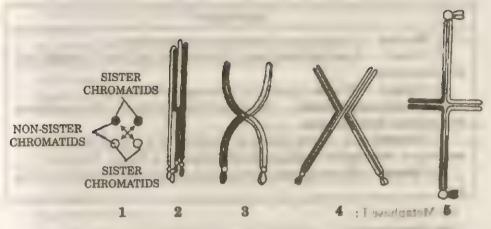


Fig. 6.13: Configurations of chromosomes during Meiotic Prophase 1

1 Sister and non-sister chromatids 2-Crossing over 3 Formation of Chiasma

4-Terminalization 5-Rotation.

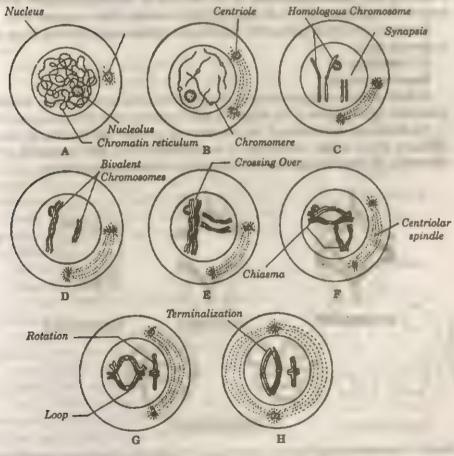


Fig. 6.14: Stages of Meiotic Prophase I in animal cell.

(A & B)-Leptotene C-Zygotene (D & E) Pachytene F-Diplotene (G & H) Diakinesis

REVISION

- [1] Bivalent Synaptic pair of homologous chromosomes.
- [2] Tetrad A pair of homologous chromosomes with four chromatids and two centromeres.
 - [3] Synapsis Process of pairing of homologous chromosomes.
- [4] Synaptonemal complex Axial protein band in between the homologous chromosomes during synapsis.
- [5] Crossing over The process of exchange of non-sister chromatids of homologous chromosomes during pachytene subphase of Meiotic Prophase I.
- [6] Chiasma The attachment of non-sister chromatids at the points of crossing over.

(B) Metaphase I:

Important events:

- (i) In animal cell, spindle is formed between the two centrioles, 180° apart.
- (ii) Homologous pair of chromosomes are arranged on the equatorial plane in such a way that their centromeres remain on the two sides of the metaphase plate directed towards the opposite poles, while their chromatids remain at the metaphase plate.
- (iii) Repulsive forces between the homologous chromosomes increase which tend to separate them.

[C] Anaphase I

Important events:

- (i) Each of the homologous chromosomes with their two chromatids and undivided centromere (dyad) moves to the respective poles by the process of disjunction.
- (ii) Anaphasic movement of chromosomes is initiated like mitosis, by the coordinated effect of the contraction of chromosome fibres and elongation of the contraction of chromosomal fibres and elongation of the continuous fibres.

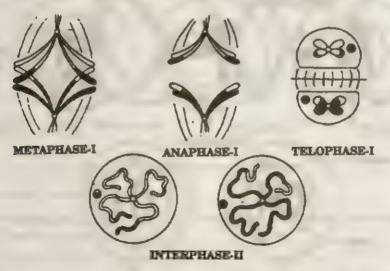


Fig. 6.15: Diagrammatic representation of different stages of Meiosis I after Prophase (including Interkinesis)

(iii) The chromosomes are distinctly separated into chromatids united at the centromere.

(iv) Chromosomes at each pole is reduced to half of the melocyte (haploid) because of disjunction.

(v) One of the two chromatids remains unchanged (parental type) while the other one is changed (recombinant type) because of crossing over.

[D] Telophase I

Important events:

(i) Chromosomes reach the two poles and nuclear membrane is reorganised.

(ii) Chromosomes become despiralised, nuclear reticulum and nucleolus reappears.

(iii) The two daughter nuclei are formed on the opposite poles with haploid number of chromosomes after the reduction of chromosome number.

(iv) The chromatin threads disappear due to hydrated condition of the nucleus.

[E] Cytokinesis I:

Important Events:

(i) The process of cytokinesis is like that of

(ii) The daughter cells have half the chromosome number of the parent cell.

(iii) The two daughter cells quickly pass on to the second meiotic division after a very short resting period.

Interkinesis (2nd Interphase):

It is a very short period between the first and second meiotic division without any significant changes. There is no duplication of DNA during this phase like mitotic interphase.

[II] Second Meiotic Division:

The two haploid cells formed as a result of first meiotic division undergoes the second meiotic division to produce four identical haploid cells. The different stages of Second Meiotic division are prophase, metaphase, anaphase, telophase and cytokinesis.

[A] Prophase II.

Important Events:

- (i) The chromosomes are visible again because of dehydration.
- (ii) The chromosomes do not exist in pairs but is made up of two chromatids and a centromere.
- (iii) Chromatids remain free from each other (difference with mitotic prophase).
- (iv) The spindle fibres appear at right angles to the spindle of first meiotic division towards the end of this stage. In animal cell, the centrosome divide and forms the centriolar spindle.
- (v) The nucleolus and nuclear membrane Fig. 6.16: Diagrammatic Representation disappear.



[B] Metaphase II: (This phase is very brief)

Important events:

- (i) The chromosomes are arranged along the equatorial line of the spindle fibres.
- (ii) The centromeres remain on the metaphase plate, while the chromatids are extended towards the poles.
 - (iii) The centromeres are attached to the spindle fibres.

[C] Anaphase II:

Important events:

- (i) The chromosome divide longitudinally with each half having single chromatid and half of the centromere.
- (ii) The separated chromatids move to the opposite poles due to the shortening of chromosomal microtubules and thus anaphasic movement of chromosomes are initiated.

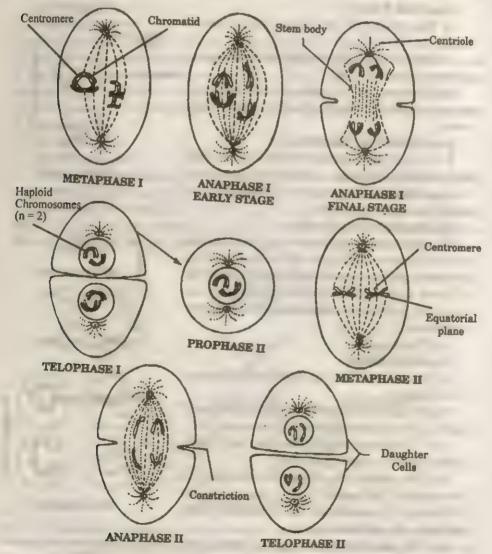


Fig. 6.17: Different stages of Meiosis in Animal cell after Prophase I.

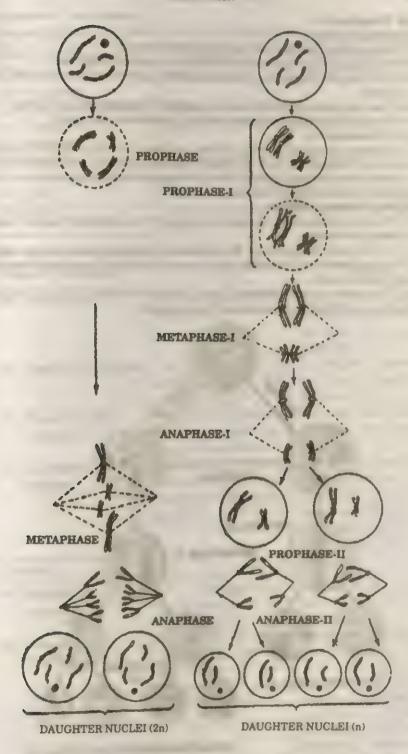


Fig. 6.18: Comparative table of Mitosis and Meiosis (Diagrammatic)

[D] Telophase II : Important Events :

(i) The daughter chromosomes reach the opposite poles.

(ii) The endoplasmic reticulum resynthesizes the nuclear membrane.

- (iii) The nucleolus organizer synthesize r-RNA and ribosomal protein and forms the nucleolus.
 - (iv) Four daughter nuclei with haploid number of chromosomes are formed.

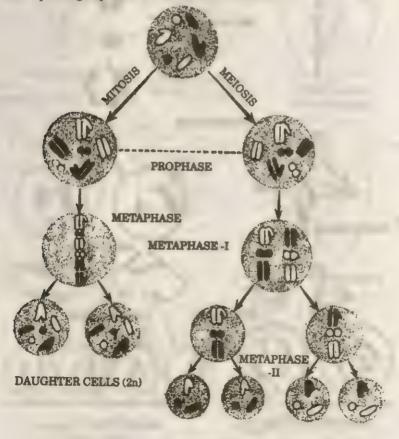
(v) The nucleus becomes hydrated and the chromosomes disappear.

[E] Cytokinesis II:

The products of second meiotic division are always four haploid cells with their chromosomes composed of both parental combination and new recombination traits. They become the functional gametes in higher organisms and undergoes sexual union to restore the original diploid chromosome status.

[F] Significance of Meiosis:

- [1] Meiosis maintains the chromosome number in a particular species through subsequent generations.
 - [2] It is an essential process for the perpetuation of sexually reproducing species.
- [3] Recombinations of hereditary units (genes) of different chromosomes take place through crossing over.
- [4] The various recombinations of genes produce variations within an organism, which after a prolonged period can result into evolution.



DAUGHTER REPRODUCTIVE CELLS (n)

Fig. 6.19: Short representation of Mitosis and Meoisis in Animal Cell (2n = 6) (Diagrammatic)

[I] Important Comparisons:

• Differences between Crossing Over and Translocation :

Points of Differences:	Crossing over	Translocation
[1] Nature of	Homologous	Non-Homologous.
Chromosomes		
[2] Phase of Cell Division	Pachytene,	Interphase.
[3] Condition of	Tetrad	Dyad.
Chromosome		
[4] Synapsis	Necessary before	Not required.
	crossing over.	
[5] Types	Reciprocal.	Simple or Reciprocal.
[6] Result	Variation in gamete	Chromosomal Aberration
	formation.	

• Differences between Mitosis and Meiosis:

Points	of Differences :	Mitosis	Melosis
	ccurrence	It occurs almost in all types of cells.	Occurs mainly in the reproductive parts of sexually reproducing organisms
[2] Nu	imber of divisions	The process is completed in one division only.	The process is completed by two successive divisions.
	ture of cells oduced	Two identical daughter cells are produced from a single mother cell.	Four daughter cells are produced from a mother cell.
	romosome mber	Chromosome number remains same as that of parent cell (Equational division).	The chromosome number is reduced to half (haploid) in the four daughter cells produced from the parent cell (Reductional division).
Propha	se		
chr	rision of comosome and the	The chromosomes divide once along with one cell division.	Chromosomes divide once along with two cell divisions. Prophase is composed of
[6] Nat	ture of ophase	Composed of one short and simple division with the absence of sub- divisional stages.	two divisions, prophase I is prolonged and complicated with five major subdivisional stages (leptotene, zygotene, pachytene, diplotene, diakinesis) Prophase II is

just like mitotic prophase.

Points of Differences	Mitosis	Meiosis
[7] Division of acceptance centromere	Each chromosome is divided into two daughter chromatids but centromere remains undivided during prophase.	Chromosome remain undivided along with the centromere.
[8] Synapsis	Synapsis does not occur between homologous chromosomes.	Synapsis takes place between homologous chromosomes.
[9] Crossing over	There is no crossing over and chiasma formation and so no exchange of genetic material.	Crossing over and chiasma formation take place causing exchange of genetic information between non-sister chromatids of homologous chromosomes.
[10]Status of nucleo- lus and nuclear membrane	The nucleolus and nuclear membrane disappear at the end of prophase.	The nuclear membrane and nucleolus also disappear.
[11] Number [12] Position of centromere	Occurs once only. The centromeres usually lie at the equatorial plane and the arms points towards the two poles.	Occurs twice (division I+ II). The centromeres of homologous chromosomes lie equidistant from the equator and extended towards the pole in the metaphase I but in metaphase II, the centromeres remain at the equatorial plane.
[13] Nature of metaphase chromosome.	The chromatids remain as dyad.	The chromatids of homologous chromosome remain as tetrad.
[14] Status of centromere	The centromere divides longitudinally leading to the sesseparation of chromosomes.	There is no need of centromeric division in metaphase I but the centromere divides like mitosis in metaphase II.
Anaphase		
[15] Number of anaphase [16] Movement of chromosomes	Occurs once only. The longitudinal segments of chromosomes (monads) move towards the two poles.	Occurs twice (anaphase I & II). In anaphase I, there is poleward movement of the entire chromosome with exchanged segments but in anaphase II, the movement is same as mitosis.

Points of Differences	Mitosis	Meiosis
[17] Number of difference telophase	Occurs once only.	Occurs twice (telophase I & II).
[18] Telophase chromosome number	The chromosome is identical in the parent and daughter nuclei.	Chromosome number is reduced to half in the daughter nuclei after Telophase I but after Telophase II, the daughter nuclei with identical chromosome number are produced.
[19] Appearance of nucleolus and nuclear mem- brane	Nucleolus and nuclear membrane appear at the end of telophase.	They appear temporarily at the end of telophase I, but permanently at the end of telophase II.
[20] Status of telophase chro- mosomes Cytokinesis; [20]	The chromosomes of the daughter cells are without genetic recombination.	In the four haploid daughter cells, half the chromosome is crossover type while the other half is non- cross over type.
[21]Product of	Two diploid daughter cells.	Four haploid daughter cells.
[22] Nature of Cytokinesis	The cytokinesis is conspicuous after karyokinesis occuring along with nuclear division in animal cell but after nuclear division in plant cell.	The cytokinesis I is very much inconspicuous but the cytokinesis II is of usual occurrence.

6.5.6. RELATIONSHIP OF CELL DIVISION WITH ALTERNATION OF GENERATION :

The life cycle of an organism can be divided into two distinct phases, the haploid gametophytic phase and the diploid sporophytic phase. These two phases alternate in the life cycle of sexually reproducing organisms. In higher organisms, fusion of 2 gametes (n) forms the 2n zygote and the sporophytic generation commences. The diploid vegetative body develops the sex organs, which undergo meiosis to produce the haploid gametes and marks the beginning of gamtophytic generation. But this phase is short lived and soon the diploid phase starts. The lower plants remain in haploid vegetative state, so here the gametes bring upon the short lived diploid phase because the zygote soon undergoes reduction division and haploid forms are regenerated.

6.5.7 RELATIONSHIP OF MEIOSIS WITH EVOLUTION:

The phenomenon of crossing over in the Pachytene subphase of Meiotic Prophase I results in the production of variation within gametes. The fusion of these variable gametes results in the production of individuals with intermediate characters, which in the long run reults in the origin of new species. In this way meiosis can pave the pathway of evolution.

6.6. Abnormal Cell Growth

The telomere of a chromosome consists of a repetitive sequence of six nucleotides, which is responsible for the synthesis of enzyme telomerase, responsible for the control of cell division. With the number of division, these nucleotides gradually reduce in number and the rate of cell division is reduced. If these nucleotides increase by any abnormal means, then the cell starts dividing at a later stage of development. This uncontrolled cell division may result in the formation of tumour or neoplasm. The phenomenon may lead to malignant cell growth or cancer.

6.6.1 TYPES OF ABNORMAL CELL GROWTH

On the basis of the nature of growth, they may be of four types but all of them may not be harmful to an organism. They are as follows:

- (a) Hyperplasia: Definition: It is abnormal growth and production of normal cells, e.g. Growth of female breast during pregnancy.
- (b) Hypertrophy: Definition: It is the increase of the size of an organ due to enlargement of the cells, e.g Increased size of striated muscles in response to increased work or exercise.
- (c) Metaplasia: Definition: It is the conversion of normal cells to abnormal cells due to physical stress or infection, e.g.: The columnar epithelial cells of bronchus change to squamous epithelial cells due to the effect of smoking.
- (d) Neoplasia: Definiton: It is the new, abnormal development of the cells. It is of two types:
- [1] Benign growth: The growth is restricted to a particular site of the body but never spreads to other parts of the body, e.g.: Simple tumour.
- [2] Malignant growth: The abnormal growth at a particular site spreads to the other parts of the body with the help of tissue fluid by a phenomenon called metastasis. Malignant growth are of the following types:—
- (i) Carcinoma: Malignant growth of the epithelial cells. It accounts for 85% of cancer, e.g.: Adeno carcinoma.
- (ii) Lymphoma: Malignancy of the lymph node resulting in excessive production of lymphocyte. It accounts for 5% of cancer, e.g.: Hodgkin's disease.
- (iii) Leukemia: Malignancy of the haemopoetic cells of red bone marrow resulting in increased production of leucocytes. It accounts for 4% of human cancer.
- (iv) Sarcoma: Malignancy of the connective tissue acounting for 2% of human cancer. It may be of various types depending upon the type of tissue affected, as for e.g: Osteosarcoma (bone), Chondrosarcoma (cartilage), Rhabedomyosarcoma (striated muscle), Leiomyosarcoma (smooth muscle), Liposarcoma (adipose tissue).
 - (v) Melanoma: Malignancy of pigment cells.
 - (vi) Glioma: Malignancy of neuroglial cells of nervous system.
 - (vii) Myeloma: Malignancy of bone marrow.

He La Cells: Human cancerous cell line donated by "Henrietta Lacks" maintained in tissue culture since 1953.

6.6.2. CHARACTERS OF CANCEROUS (MALIGNANT) CELLS

[1] Immortalization: The cells become immortal and can be safely maintained in tissue culture, generation after generation.

- [2] Loss of contact inihibition: The cells do not stop growing when come in contact with each other.
 - [3] Reduced cellular adhesion: The cells lose the power of surface attachment
- [4] Invasiveness: The cells develop increasing invading property for increased protease activity.
- [5] Loss of anchorage dependence: The cells can grow and divide even in the absence of a substratum.
- [6] Change in cell membrane: The constituents of glycolipids and glycoproteins in a cell membrane change.
- [7] **Decreased cytoskeleton**: The amount of microtubules and microfilaments is reduced due to increased depolymerisation.
- [8] Increased sugar utilization: The rate of sugar utilization increases with the increase in the rate of glycolysis.
- [9] Increased proteolytic enzyme secretion: New proteolytic enzymes like plasmin and protease are produced, which changes the structural conformity of the existing cells.

6.7. Matters to recollect

- Amitosis: Direct cell division without spindle formation.
- Mitosis: Indirect cell division with spindle formation producing identical sets of chromosomes in the daughter cells.
- Meiosis: Cell division in which the chromosome number is reduced to half. It includes one chromosome division but two cell divisions.
- Karyokinesis: The first phase of cell division, which includes division of the cytoplasm.
- Cytokinesis: The second phase of cell division which includes division of the cytoplasm.
- Prophase: The first major phase of nuclear division followed by the disappearance of nucleolus and nuclear membrane.
- **Prometaphase**: A short phase after prophase when the chromosomes are arranging themselves on the equatorial plane.
- Metaphase: The second major phase of nuclear division when the arrangement of the chromosomes on the equatorial plane is completed and the spindle fibres are attached to the centromere.
- Anaphase: The third major phase of nuclear division during when the daughter chromosomes separate along with the centromeres.
- Telophase: The final stage of nuclear division when the chromosomes reach the opposite poles and nucleolus and nuclear membrane reappear.
- Centromere: The primary constriction region of the chromosomes to which the spindle microtubules are attached.
- G_0 stage: Arrested G_1 stage in animal cells where division is suspended, like neurone.
- Synapsis: The pairing of homologous chromosomes during the zygotene subphase of meiotic prophase I.

- Crossing over: The exchange of genetic material between two non-sister chromatids of homologous chromosomes during the pachytene subphase of meiotic prophase I.
- Chiasma: The attachment of non-sister chromatids at the points of crossing over during diplotene subphase of meiotic prophase I.
- Terminalization: The pushing of chiasmata to the terminal ends of chromatids.
- Homologous chromosomes: The pair of chromosomes derived from the two parents pairing with each other during pachytene subphase of meiotic prophase I.
- Leptotene: The first major subdivisional stage of meiotic prophase I, during when the chromatid threads uncoil to form slender chromosomes.
- Bouquet Stage: The polarised stage of chromosomes present during leptotene, when the converged ends of chromatids form loops on the side of the nucleus.
- Zygotene: The second major subdivisional stage of meiotic prophase I during when synapsis takes place.
- Pachytene: The third major subdivisional stage of meiotic prophase I during when crossing over takes place with the recombination of homologous chromatids.
- Diplotene: The fourth major subdivisional stage of meiotic prophase I during when crossing over takes place with the recombination of homologous chromatids.
- Diakinesis: The final subdivisional stage of meiotic prophase I during when reduction in the number of chiasmata takes place.
- Recombination: Recombination involves exchange of genetic information due to crossing over.
- Rotation: The movement of chromosome arm about 80° 180° on the chiasma point.
- Anaphase movement: The separation of chromatids or homologous chromosomes due to polymerisation and depolymerisation of spindle elements.
- Astral or Amphiastral mitosis: The mitotic division in which the spindle fibres are formed from the centriolar astral rays.
- Anastral mitosis: Mitosis division in which spindle formation takes place from the nucleoplasm or nuclear membrane.
- Mitotic apparatus: The spindle, centriole and aster together are designated as mitotic apparatus.
- Synaptonemal complex: The axial protein band in between the homologous chromosomes correlated with synapsis and crossing over.
- Stem body: The structure formed by the reduction of spindle fibres at the equatorial region during cytokinesis in animal cell.
- Contractile ring: The structure formed by the reduction of spindle fibres at the equatorial plane in certain animal cell.
- Cancer: Uncontrolled cell proliferation due to the rapid karyokinesis which does not give enough time for cytokinesis.
- Hyperplasia: Increased production of cells of a tissue or organ.
- Hypertrophy: Increase in the size of an organ due to hyperplasia.
- Neoplasia: Development of new abnormal cells which may be stationary (benign) or spreading (malignant).
- Metastasis: Spreading of malignancy from one organ to other via tissue fliud.

6.8. Summary

There are three types of cell divisions as amitosis, mitosis and meiosis. Amitosis and mitosis maintains the constant chromosome numbers of somatic cells. Meiosis reduces the chromosome number to half and keeps the chromosome number constant in sexually reproducing organisms. Amitosis or direct cell division is the method of asexual reproduction in unicellular organisms like bacteria, fungi and protozoa. In eukaryotic cells, anastral mitosis is noted in plant cells but astral or amphrastral mitosis is noted in animal cells. In prophase, condensation of chromosomes, spindle formation and disappearance of nucleolus and nuclear membrane takes place. The prometaphase is the preparatory phase for metaphase. During metaphase, the chromosomes are arranged on the equatorial plane and the spindle fibres get attached to their centromeres. In anaphase, the centromere divides and the chromosomes divide longitudianally, The separated chromosomes move to the opposite poles due to polymerisation and depolymerisation of the spindle fibres. During telophase, the sister chromatids aggregate to the poles, nucleolus and nuclear membrane reappear leading to the formation of two daughter nuclei in the two poles. Telophase is followed by cytokinesis in plant cell by the formation of cell plate but in animal cell, it occurs by the formation of two lateral constrictions, which is simultaneous with nuclear division. Meiosis occurs in the gamete producing cells of sexually reproducing organisms called meiocytes. Meiosis not only reduces the chromosome number to half to keep the chromosome number constant in a particular species through subsequent generations, but also produces variations through recombination of genes and thereby helping in evolution. It includes two separate divisions, the first one is reductional, while the second one is equational (i.e same as mitosis). The first meiotic prophase is a long and complicated phase.

The different subphase of meiotic prophase I are preleptotene, leptotene, zygotene, pachytene, diplotene and diakinesis. Preleptotene is a preparatory phase, when the nuclear reticulum uncoils to form the chromosomes. During leptotene, the chromosomes become distinct, they undergo synapsis with the formation of synaptonemal complex in the zygotene. In pachytene, crossing over or recombination between non-sister chromatids of homologous chromosomes takes place. During diplotene, the formation of chiasmata and terminalization takes place. In diakinesis, the terminalization continues and the number of chiasmata is reduced. During the rest three phases of meiosis I, viz. metaphase I, anaphase I and telophase I, the homologous chromosomes separate, move towards the opposite poles and form two daughter nuclei with haploid number of chromosomes. The interkinesis is a short phase between meiosis I and II and during meiosis II, the chromosomes divide like mitosis with the four substages viz. prophase II, metaphase II, anaphase II and telophase II. Ultimately four haploid daughter cells are formed Abnormal cell division results due to the irregular activity of the enzyme telomerase. It may be of four major types vtz. hyperplasia, hypertrophy, metaplasia and neoplasia. Neoplasia may be either beingn or malignant, malignancy can be of various types like carcinoma, sarcoma, lymphoma etc. It induces various physiological and structural changes within a cell, can spread via tissue fluid to other organs by the phenomenon of metastasis.

6.9. Naming/Discovery/Discoverer

- [1] Van Mohl and Virchow (1850): They separately discovered cell division.
- [2] A. Schneider (1873): Described chromosomes for the first time.
- [3] H.Fol (1873): Described the spindle formation with astral rays.
- [4] F. Strasburger (1875): Described mitosis in plant cells.
- [5] Schleicher (1878): Coined the term karyokinesis.
- [6] W. Flemming (1879): Introduced the term chromatin and described the longitudinal splitting of chromosome during nuclear division of animal cells. In 1882, he coined the term mitosis.
- [7] E. Van Benden (1883): Showed in *Ascaris* that the number of chromosomes in the gametes is half of that of the somatic cell.
- [8] T. Boveri (1888): Described the structure of centriole.
- [9] J. Loeb (1900): Discovered artificial parthenogenesis.
- [10] E. Strasburger (1901): Introduced the term plasmodesmata.
- [11] T.H. Montgomery (1901): Showed the pairing or synapsis of homologous chromosomes during reduction division.
- [12] J. B. Farmer and J.E. Moore (1905): Coined the term meiosis for reduction division.
- [13] Jassens (1909): Showed that chiasma formation is a consequence of crossing over.
- [14] A. Kossel (1910): Got the Nobel prize for investigating the chemistry of nucleus.
- [15] Dustin (1900): Discovered colchicine induced mitosis in plants.
- [16] C.F. Robinow (1944): Demonstrated the structure of nucleus (nucleoid) in bacteria.
- [17] Howard and Pele (1953): Denoted the subphases of interphase, viz. G₁, S and G₂.
- [18] Harris and Watkins (1965): Produced first heterokaryons of mammalian cell by the virus induced fusion of human and mouse cells.
- [19] Rao and Johanson (1970): Discovered various proteins like SPF, MPF that promote DNA synthesis during interphase.
- [20] Haplar et.al (1980): Explained the role of Ca⁺⁺ ions in the anaphase separation of chromosomes.
- [21] Albert et al (1989): Denoted various types of cell cycle and also explained the role of cytoskeleton in mitosis.
- [22] Burns and Bottino (1989): Showed the digestion of nucleolus at the end of prophase-I by the enzymatic action of ribosome (ribozyme), though Cech and Altman (1989) got the Nobel prize for the discovery of ribozyme.

6.10. Answers to special questions:

[1] Who discovered cell division?

Ans. Van Mohl and Virchow separately discovered cell division in 1850.

[2] What are the causes of cell division?

Ans. Doubling of DNA content and maximum elongation of cell due to accumulation of cytoplasm.

[3] Name the different stages of cell cycle? (J.E.E. 1995)

Ans. The different stages are G, S, G, and M.

- [4] (a) What is G₀ stage? (b) Where is it located in cell-cycle? (J.E.E. 1995) Ans. (a) G₀ stage is the arrested G₁ stage in cells, where division is suspended as for e.g. Nerve cell. (b) It is present at the onset of G₁ stage.
- [5] In which phase of cell cycle, the cell becomes double in size?

 Ans. G, phase.
- [6] Which phase of cell division shows normal protein synthesis? Ans. Interphase.
- [7] In which phase of cell division, DNA duplication takes place?

(J.E.E. 1995, '96)

Ans. Synthetic (S) stage of interphase

[8] In what stage and from where does the nuclear membrane originate?
(J.E.E. 1988)

Ans. The nuclear membrane originates at the late telophase. It originates from the endoplasmic reticulum.

[9] What is interzonal spindle fibre? (J.E.E. 1988)

Ans. The fibres which extend between the two poles of a cell at the anaphase stage.

[10] At which stage of mitosis, the centromere divides into two? (J.E.E. 1995)
Ans. Anaphase stage.

[11] What is somatic pairing?

Ans. When the chromatids after duplication do not separate, but remain side by side, this condition is called somatic pairing.

[12] What is endomitosis?

Ans. Consecutive division of the chromatid at interphase stage to form a polytene chromosome is known as endomitosis.

[13] What is oncogene?

Ans. The gene responsibile for inducing malignancy in a tissue, which normally remain in recessive state but is activated in presence of a carcinogen.

[14] What is free cell division?

Ans. The cell division taking place in suspension as for e.g. in the liquid endosperm of coconut.

[15] What is D-phase?

Ans. The cytokinesis in a cell division is referred to as D phase.

[16] What are the enzymes associated with crossing over? Ans. Endonuclease and ligase.

[17] Where does meiosis takes place in pea-plant and guineapig?
(J.E.E. 1990,'98)

Ans. Peaplant— Antheridial mother cell in male and embryo sac mother cell in female.

Guineapig—Primary spermatocyte in testis of male and primary oocyte in ovary of female.

[18] What is Ribozyme? Ans. The enzyme like activity of ribosome dissolving the nucleolus at the end of prophase. [19] What is S.P.F?

Ans. The 'S' phase promoting factor responsible for activating the process of DNA replication during interphase.

[20] What is contractile ring?

Ans. The structure formed from microfilament during cytokinesis in certain animal cells.

[21] What is metastasis?

Ans. The spreading of malignancy from one organ to other with tissue fluid.

[22] What is Telomerase?

OC. Specific Answer type:

[2] What is genome?

What do you mean by haploid number of chromosomes?

Ans. The enzyme coded by the telomeric nucleotide responsible for controlling cell division.

[23] What is the most common type of cancer?

Ans. The most common type of cancer is cancer of epithelial tissue or carcinoma, which is the cause of 80% cancer.

[24] Name two proteolytic enzymes released by cancerous cells.

Ans. Plasmin and protease.

EXERCISE

	EXERCISE	
●A.	Eassy type or Long Answer type:	
[1]	In which organ do the meiosis occurs? How four haploid cells are formed f	rom a meiotic cell division? [J.E.E. 1991] (Ans. 6.5.5)
[2]	What are the sub-stages of prophase I in meiotic cell division? In what sub- Mention the significance of meiosis.	[J.E.E. 1992] (Ans. 6.5.5)
[3]	When and where meiosis occurs in the body of an organism? What is importance.	crossing over? Mention its [J.E.E. 1981] (Ans. 6.5.5)
[4]	What is heterotypic cell division?	[J.E.E. 1987] (Ans. 6.5.5)
[5]	Why meiosis is called reductional division? Where does it occur? Descri	the the first four stages of
	meiosis.	(Ans. 6.5.5)
[6]	Where does meiosis take place? Describe briefly the meiotic cell division.	(Ans. 6.5.5)
[7]	Give an account of Prophase I of meiosis.	(Ans. 6.5.5)
[8]	What is malignant growth? What are itss different types? How can it spre-	ad ? (Ans. 6.6)
191	State the various changes taking place in a cancerous cell.	(Ans. 6.6.2)
● B.	Short answer type:	
[1]	Briefly describe the interphase stage of mitosis?.	[T/H.S. 1985] (Ans. 6.5.4)
[2]	What do you mean by homologous chromosomes?	(Ans. 6.5.5)
[3]	What do you mean by amitosis?	(Ans. 6.5.1)
[4]	Why cells divide?	(Ans. 6.2)
[5]	What do you mean by terminalization?	(Ans. 6.5.5)
[6]	What is crossing over?	(Ans. 6.5.5)
[7]	What is the importance of interphase in cell division?	[J.E.E. 1985] (Ans. 6.5.4)
[8]	Why meiosis is called reduction division?	(Ans. 6.5.5)
[9]	What is bivalent?	(Ans. 6.5.5)
[10]	What is interphase stage?	(Ans. 6.5.4)
[11]	Mention the two main significances of meiosis.	(Ans. 6.5.5)
[12]	Mention the two characteristics of meiosis.	(Ans. 6.5.5)
[13]	Where does meiosis occur in plant?	[J.E.E. '90] (Ans. 6.5.5)
[14]	What is metastasis?	[J.E.E. '94] (Ans. 6.6)
[15]	What is neoplasm?	[J.E.E. 1994] (Ans. 6.6.1)
[16]	What is sarcoma?	[J.E.E. 1991] (Ans. 6.6.1)
[17]	What is lymphoma?	(Ans. 6.6.1)
[18]	What is telomerase?	(Ans. 6.6)

(Ans. 6.5.5)

(Ans. 6.5.5)

[3	What is gap period?		(Ans. 6.5.4)
[4		[J.E.E. 1991]	(Ans. 6.5.4)
			(Ans. 6.5.5)
[5			(Ans. 6.5.5)
16			
[7			(Ans. 6.5.5)
[8]	What is bivalent?		(Ans. 6.5.5)
[9	What is synapsis?		(Ans. 6.5.5)
110	What is chiasma?		(Ans. 6.5.5)
j11			(Ans. 6.5.5)
112			(Ans. 6.5.5)
[13		[J.E.E. 1995]	(Ans. 6.5.4)
	11		(Ans. 6.6.2)
[14			(Ans. 6.6.1)
[15			(Ans. 6.6.2)
[16	Y Company of the comp		
[17	What is benign growth?		(Ans. 6.6.1)
●D.	Distinguish between:		
Ψ.υ.			18 ma 6 E 42
			(Ans. 6.5.4)
[2	Leptotene and Zygotene		(Ans. 6.5.5)
[3	Metaphase I and Metaphase II		(Ans. 6.5.5)
[4			(Ans. 6.5.5)
[5			(Ans. 6.5.5)
[6			(Ans. 6.5.5)
,	4 4 4 4		(Ans. 6.5.5)
17	Homotypic and necessianal Division		(Ans. 6.5.5)
[8			(Ans. 6.5.5)
19			(Ans. 6.6.1)
[10			(Ans. 6.6.1)
[11	Metaplasia and Neoplasia		
[12	Malignant and Benign growth		(Ans. 6.6.1)
[13	Anaphase I and Anaphase II		(Ans. 6.6.5)
[14			(Ans. 6.6.1)
• E.	Short Notes:		
[1	[Interphase		(Ans. 6.5.4)
[2	· · · ·	[J.E.E. 1995]	(Ans. 6.5.4)
[3			(Ans. 6.5.3)
[4			(Ans. 6.5.5)
			(Ans. 6.5.5)
[5			(Ans. 6.5.5)
16			(Ans. 6.5.5)
F			(Ans. 6.5.5)
[8			(Ans. 6.5.5)
[9	Diakenesis		(ANs. 6.5.5)
[10	Bivalent		
[11	Crossing over		(Ans. 6.5.5)
[13	Amitosis		(Ans. 6.5.1)
j1:	· · · · · ·	[J.E.E. 1987]	
(1)	· · · · · · · · · · · · · · · · · · ·		(Ans. 6.5.5)
(1:		[J.E.E. 1987]	
		[J.E.E. 1987]	(Ans. 6.5.5)
110	•		(Ans. 6.5.5)
[1]	1		(Ans 6.6.1)
[13			(Ans. 6.6.1)
[19			(Ans. 6.6.1)
[21			
[2] Leukemia		(Ans. 6.6.1)
•	Put / Mark for correct statement		
1	I Soundle formation takes place during-Prophase/Anaphase/Metaphase.		
	Spindle is formed in animal cell from-Cytoplasm/Astral ray/E.R.		
	a		
	- 1 - Destructions/Zerostons/Destructions		
į:	Synapsis takes place during-rachytene Zygotene rachytene.		

[6]	DNA duplication takes place during-Metaphase/Interphase /Prophase
171	Centromere divides during-Metaphase/Anaphase/Telophase.
[8]	Amitosis takes place in-Bacteria/Brown Algae/Hydra.
191	Malignancy spreads by Epistasis/Metastasis/Hypostasis.
10]	Carcinoma is the cancer of Muscle tissue/Nerve tissue/Epithelial tissue.
G.	Fill in the blank with correct word.
[1]	DNA synthesis occurs during
[2]	is a consequence of crossing over.
[3]	The pairing of homologous chromosomes is called
[4]	Bouquet stage occurs during subphase of meiotic prophase I
[5]	The mitosis is characteristic of plant cell.
[6]	is the spreading of malignancy from one tissue to the other.
H.	Put ✓ Mark on Yes or No for correct answer:
[1]	Amphiastral mitosis is a characteristic of plant cell-Yes/No.
[2]	The process of amitosis occurs in bacteria-Yes/No
[3]	Meiosis occurs in the spore mather cell-Yes/No.

[4] Interphase is a resting phase-Yes/No.[5] The second division of meiosis is reductional in nature-Yes/No

[6] Schneider discovered cell division-Yes/No.

[7] The cancer of the connective tissue is called carcinoma-Yes/No

[8] The process of terminalization occurs after chiasma formation Yes/No

	(F)		(G)		(H)
[1]	Metaphase	[1]	Interphase	[1]	No
[2]	Astral rays	[2]	Chiasma formation	[2]	Yes
[3]	Cytokinesis	[3]	Synapsis	[3]	Yes
[4]	Pachytene	[4]	Leptotene	[4]	No
[5]	Zygotene	[5]	Anastra!	[5]	No
[6]	Interphase	[6]	Metatasis.	[6]	No
[7]	Anaphase			[7]	No
[8]	Bacteria			[8]	Yes.
[9]	Metastasis				
101	Epithelial tissue.				

Genetics

Topics Discussed: Introduction; Pre-mendelian views of heredity; Discovery of Mendel's laws of heredity. Reasons of Mendel's selection of garden pea; Mendel's experiments on monohybrid and dihybrid crosses. Mendel's laws of heredity; Backcross, Test cross, Incomplete dominance, Gene interaction, Multiple affele, Multiple gene. Pleiotropism, Linkage, Crossing over, Chromosome mapping, Sex linked inheritance. Colour blindness and Haemophilia, Mulation. Gene alteration and chromosomal afteration, importance of multation; Gene structure and function; Genetic code. Mechanism of protein synthesis.

Introduction

Every plants and animals of the living world are maintaining their race through creation of new individuals by the process of reproduction. New individuals show similarity to their parents. So we can say that the characteristic features of each species are transmitted to their pffspring from generation to generation. As for example, offspring of a man maintains the traits or characteristics of man that never gives any wrong impression about similarities with other animals. The offspring of a cat looks like a cat. Mango trees are developed from the seeds on mango. Such innumerable examples are present in the living world. Man has noticed from the ancent times that the characteristics of the parents are expressed to their progeny. Because the parents and their progeny are deeply attached to each other. Fusion of sperm and ovum of the parents, gives rise to a zygote and zygote develops into a matured individual. So we can say that the chracteristics of the parents are transmitted to the offspring through their gametes (sperms and ova). But the offspring never show the exact similarity with their parents. Though the fundamental similarities about structural and physiological functions are present in the offsprings of the same parents or among the same species yet the differences are also observed. These differences in the living organisms are called variation. These variations are playing a great role in heredity. But variations due to environment are merely temporary and these temporary variations have nothing to do with the next generation. So it should be remembered that the hereditary variations among the offsprings of the same parents are mainly occur in sexually reproducing organisms. These variations are transmitted from one generation to the subsequent generations.

But before Mendel there was lack of scientific concept about the heredity. Though the human beings were trying to develop the better variety of food crops and domestic animals since the begining of human civilization. The first scientific concept about inheritance came from Gregor Johann Mendel in the middle of 19th century.

7.1. Definition of genetics

The branch of science that deals with the process of inheritance of chatacters and their variations among the related organisms is called genetics. Variations are the differences that occur among and within species. Hereditary variations are present in the offspring of the same parents as well as in the offsprings of different parents, i.e.

these variations are inheritable. So we can say that the inheritable variations are the raw materials of evolution.

7.2. Some pre-mendelian views of heredity

Throughout the ages even before Mendel, peoples have tried to explain the meachanism of heredity. Early plant and animal breeders though they have developed the improved varieties of rice, maize and also the pedigress of horse and cow by application of certain methods; yet they were not aware of the pronciples of heredity. Some cencepts or theories that have been put forwarded in the Pre-Mendelian era to explain the mechanism of inheritance are given below in short.

- [1] Fluid theory: One of the earliest views on heredity was put forwarded by a celebrated Greek philospher and naturalist, Aristotle (350-BC). He was of idea that mixing of the two seinen fluids of the parents during coition, the offspring was produced. He thought that the semen of man is highly purified form of blood and the menstrual fluid which is regarded as semen of woman is less purified blood. As the inheritance was due to mixing of such blood of the parents, so this theory of heredity was known as fluid theory. Aristole believed in direct inheritance of characters. This idea was prevailing for many centuries.
- [2] Preformation theory: With the discovery of the gametes which are regarded as the physical basis of heredity in the 17th, century, it was suggested that the hereditary traits (characteristic) must be transmitted either through sperm or egg or both. Leeuwenhoek (1677) thought that miniature form of human being is present in hte sperm and if sperm is introduced into a woman's womb then it develops into a young ones. The ovum provides only the proper environment for nutrition and dvelopment. Subsequently this preformed miniature individual was called 'homunculus'. As the concept was in vougue that the sex cells contain preformed miniature individual, so this theory was known as Preformation theory. In the 19th, century K.F. Wolf, a German scientist experimentally proved that the 'homunculus' like structure cannot exit either in sperm or ovum. So this theory was rejected subsequently and did not last long.
- [3] Pangenesis theory: In the 19th, century the well known naturalist Charles Darwin (1868) suggested that every part of the body produces minute microscopic structures that are called 'genimules' or 'pangenes'. These pangenes are transported to the sex organ through blood and ultimately collected into the gametes. During fertilization, the pangenes of both the parents are mixed or blended together and determining the traits of the offspring. The theory as proposed by Chatles Darwin was known as Pangenesis theory. Later it was evident that Darwin's Pangenesis theory was also based on imagination rather on facts.

7.3. Discovery of Mendel's laws of heredity

Gregor Johann Mendel was an Austrian monk and he joined the Augustanian Monastery at Brunn in Austria (now in Czecholovakia). Though he was a monk yet he developed the scientific attitude as because he had his science education. Mendel made his hybridization experiments in the garden of the Monastery. He conducted the hybridization experiments on garden peas (*Pisum sativum*) for a period of eight years from 1856 to 1864.

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In 1865, Mendel delivered lecture in the 'Natural History Society' at Brunn on his experimental results of garden pea. The classic paper of Mendel was published in the next year 1866 in an abscure journal of the Natural History Society. Unfortunately his remarkable piece of work on heredity remained unnoticed for many years; perhaps the biological world at that time was busy with the discussion of the 'Origin of species' published by Darwin or biologists could not understand the statistical data put forwarded by Mendel at that time. So biologists failed to give the due importance of his classical paper during his life time.

In 1900 three biologists, such as Hugo de Vries of Holland, Eric von Tschermak of Austria and Karl Correns of Germany worked independently but came to the same conclusion as Mendel. These three biologists re-discovered the Mendel's laws of inheritance. Thus the genetics, a younger branch of biology established in 1900. Since then Mendel is considered as the pioneer of modern genetics. So he is now regarded as the 'father of genetics'. Subsequently, biologists applied Mendelian principles to both plants and animals and realised the importance of the laws of inheritance as deduced by Mendel.

• What is Mendelism? Mendel's hybridization experiments, analysis of the experiments and formulation of laws of inheritance are all collectively known as Mendelism.

A BRIEF LIFE-SKETCH AND SCIENTIFIC CONTRIBUTIONS OF MENDEL

ENUEL		
1822 (July 22nd.	.) :	Born In Heizendorf, a village in Silesia.
1840		Graguated.
1843		Admitted Augustanian Monastery, Brunn (Austria).
1847		He became a monk.
1849		Appointed temporary teacher.
1853	:	Became member of zoological-Botanical Society at Vienna.
1854	:	Wrote a letter to Zoological-Botanical society about the
		damage done by the pea-weevil.
1862	:	Became founder member of 'Natural History Society' at
1002		Brunn.
1865	:	Delivered two lectures (8th. February and 8th March) on
1005		his garden nea experiments at 'Natural History Society'.
1866	:	His classic work 'Experiments in plant Hybridization
1000		in German language published in the Annual Proceedings
		of the Natural History Society.
1868		Elected abbot Monastery of St. Thomas.
1870		Papers on Hicracium and Brunn tornado published in the
10/0		proceedings of the Natural History Society.
1004	4	Died in 6th January.
1884		Dior in Am annual

7.4. Hybridization procedure

It is essential to known the procudure of artificial hybridization in plants. This procedure is followed by certain steps and these steps are described below.

[1] Collection of parents:

It is essential to collect the parent plants from the local areas for hybridization experiment. As for example, different varieties of pea plants were distributed in the surrounding wild areas of the monastery where Mendel made his experiments. After selection of certain varieties, Mendel collected the pea plants from the surrounding wild environment for his experimental material.

[2] Selection of pure parental generation:

Self fetilizations are to be made to verify the purity of the characters of the selected plant material. For this purpose, self-fertilizations are allowed in the subsequent generations and if the chracter or characters on which the experiments are to be made expressed unchanged on the subsequent generations, then these plants are accepted as pure parental generation. This type of parents are selected for hybridization experiment.

[3] Artificial cross-pollination:

[i] In case of bisexual flower (as in garden pea) of the selected pure parents, the anthers are to be removed before maturity and this is done carefully by opening of the flower before blossom with the help of fine forcep or scissor. The operation of removal of anthers is known as emasculation.

[ii] Just after removing of the anthers from the bisexual flower, the stigma is covered by polythene bag so that there will be no pollination by foreign pollens.

[iii] In case of unisexual parent plant, the male and female flowers have to be covered separately by polythene bag before maturity. Thus the foreign pollens neither mix up with the male flower nor cross-pollination can occur in female flower.

[iv] After dehiscence, the matured pollens are collected either in the paper bag or petridish. Now the covering of the emasculated flower is removed and the collected pollens are dusted on matured stigma. Afterwards the female flower is covered again by polythene bag. An inidication tag is attached after completion of the artificial cross-pollination between the selected parents. After a definite period matured seeds are collected and sown to study F₁ generation.

7.4.1. REASONS OF MENDEL'S SELECTION OF GARDEN PEA IN HYBRIDIZATION EXPERIMENT

Mendel selected garden pea as the plant material for his experimants due to the following advantages.

[1] Flower of the pea plant are bisexual. The andraecium and gynaecium of the

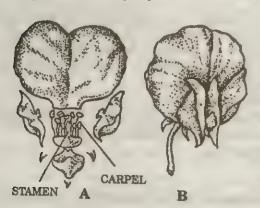


Fig. 7.1: Showing a complete flower of pea plant. (A) Displaying the different parts of a flower including andraecium and gynaecium, (B) a complete flower.

flower are more or less completely covered by the petals and so the pollen grains of other flowers cannot enter inside the flower easily. Naturally self-fetilization occurs in the flower. But in time of necessity, artificial cross-pollination can be done.

[2] Garden pea plants possess well defined varieties of characters.

[3] A pea plant can be crossed with other pea plant having alternative character, then hybrid, or heterozygous plants are developed. These hybrid plants ate fertile having power of development of the subsequent generation.

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[4] Pea plants can tolarate the extreme climate; as a result, they can be reared easily in the garden.

[5] Due to their short life-span (annual plant), hybridization experiments can be carried out in many generations within a short period.

7.5. Mendel's experiments

Mendel collected the different varieties of garden pea plants (*Pisum sativum*) from the surrounding wild environment. Mendel then carried out self-pollinations of those collected pea plants through subsequent generations only to prove their purity in relation to the specific selected characters. When he observed that the specific characters of those plants were handed over from generation to generation, he was satisfied about their purity and designated them as pure pea plant. As for example, tall pea plants after self pollination developed into tall plants only. After that he made hybridization experiments between the alternative characters of the two pure pea plants and those two pure plants were regarded as parental generation or 'P' generation. He made experiments on seven characters (traits) and their contrasting alternatives of garden pea plant are — [i] Tall and dwarf plant, [ii] Round and wrinkled seeds, [iii] Yellow and green cotyledons, [iv] Coloured and white seed coat, [v] Axial and terminal flowers, [vi] Inflated and constricted pods, [vii] Green and yellow pods.

During hybridization experiments, Mendel carefully removed the statemens from any one flower before maturation, so that no self-pollination could occur. Later after maturation he transferred the pollen grains from another of a pure plant and artifically cross pollinated by dusting emasculation flower. Now he covered the flowers with bag. The seeds that produced by cross-pollination were collected for planation.

7.5.1. MONOHYBRID CROSS

(GK. monos = single, hybrida = mixed offspring)

Definition: A cross between the two parents involving a single pair of contrasting characters is called monohybrid cross.

Experiment that made by Mendel on the length or height of the garden pea plant is described below along with the explanation of the experiment.

• Description of the experiment :

Mendel selects a pure pea plant of 6 to 7 feet height and another pure pea plant of $\frac{3}{4}$ th. to $1\frac{1}{2}$ feet height for his hybridization experiment. 6 to 7 feet height is regarded

as tall plant and $\frac{3}{4}$ th. to $1\frac{1}{2}$ feet height is treated as dwarf plant. They are regarded as 'P' (parental generation) generation. Carefully, artificial cross-pollination has been done by Mendel between the pure tall and pure dwarf plants of the parental generation, i.e. pollen grains of the tall plant are transferred to the stigma of the dwarf plant or pollen grains of the dwarf plant are transferred to the stigma of the tall plant. As a result, cross-fertilization takes place between the pollen grains of one plant with the ovum of the other plant. After maturation, seeds are collected and sown in his experimental garden for germination. It has been observed that all the plants become

tall. All these progenies of tall plants that are obtained after crossing of the parents are regarded as the F, generation or first filial generation.

Now the tall plants of F_1 generation are allowed to self-pollinated and subsequetly self-fertilization occured. These self-fertilized seeds are collected and sown in the garden for germination. He observed that all the plants were not tall, rather some of the plants became dwarf. So the tall and dwarf plants of this progeny were designated as F_2 generation or second filial generation. Mendel observed that 75% plants became tall and 25% plants became dwarf in F_2 generation. The proporation of tall and dwarf plants of F_2 generation is approximately to a ratio of 3:1. This ratio is knows as phenotypic ratio.

P = PURE PARENTAL GENERATION

F, = FIRST FILIAL GENERATION

F = SECOND FILIAL GENERATION

F = THIRD FILIAL GENERATION

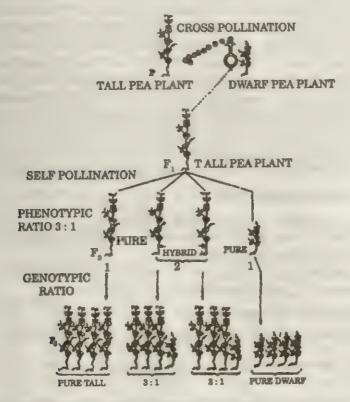


Fig. 7.2: Diagrammatic representation of—monohybrid cross of Pea plant

Progeny of F_2 were allowed to self pollination, as a result self-fertilization occured. The seeds that were produced in self-fertilization, sown in his experimental ground and allowed for germination. He observed that out of the 75% tall plant of F_2 generation, 25% become pure tall and the remaining 50% tall plant were hybrid tall and the 25% of the dwarf plant of F_2 generation developed only dwarf plant, *i.e.* they were pure dwarf plant of F_2 generation developed only dwarf plant, *i.e.* they were pure dwarf plant. The offsprings of this progeny were designated as F_3 generation (third filial generation).

Mendel subsequently hybridized the remaining 6 sets of monohybrid experiments with six pairs of contrasting characters of garden pea plant and obtained more or less the same results as before.

Analysis of the experiment: Mendel analysed the result of monohybrid crosses in the following ways. Mendel thought that each parent transmitted a 'factor' to their progeny. Each character (trait) of the parent plant dependent on a specific factor and the two contrasting characters possess two factors that remain in pair. Modern scientists designated these factors as genes. Tall and dwarf parents transmitted their tall and dwarf factors to each offspring of the F_1 generation through their gametes, i.e. each offspring received both tall factor as well as the dwarf factor from their parents. But the factor responsible for tallness is dominant over the factor responsible for dwarfness and so all the plants of F_1 generation are tall. Offsprings of F_1 generation possess both the factors for the length of the plant. Bur these two factors are separated in the F_2 generation, so both the tall as well as dwarf plants have been developed in the experiment. So reappearance of both the characters in F_2 suggests that alternative factors of a character have not been blended each other rather they retained their own identify in F_1 hybrid plants and also transmitted unchanged in subsequent generations.

Explanation of the experiments:

By using the symbols for the dominant and recessive characters, we can show that the expressed or phenotypic monohybrid ratio 3:1 of dominat to recessive forms of a character in the F₂ generation is in reality 1:2:1 ratio (25% pure dominant, 50% hybrid dominant and 25% pure recessive) in genetic constitution. The following chart (Table 1) of a monohybrid cross between a pure tall pea plant and a pure dwarf pea plant summarise the results of Mendel's experiment.

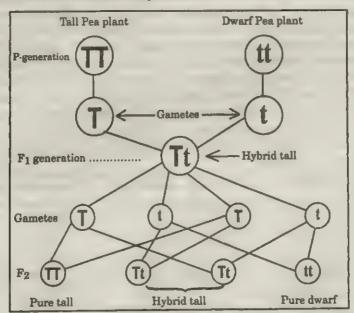
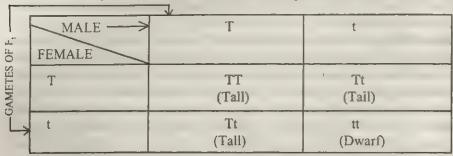


Table 1: Symbolic explanation of Monohybrid cross in pea plant.

Table 2: Showing Phenotypic and genotypic constitution of F, through Punnett Square (Chequer board)



F, Phenotypic tall = 3 and

Phenotypic dwarf = 1

So Phenotyoic ratio 3:1

Genotypically 1/4 pure tall, 1/2 hybrid tall and 1/4 pure dwarf

So Genotypic ratio 1:2:1 (1TT:2Tt:1tt)

The tall and dwarf pea plants of parental generation (P) are in pure form and so two factors or genes are in similar nature in each parent, i.e. tall plant 'TT' and dwarf plant 'tt'. During the formation of male and famale gametes the two factors are separated and each gamete of tall plant carries only 'T' and each gamete of dwarf plant carries only 't' factor or gene. So in each homozygous plant only one type of gamete is formed. After fertilization zygote contains both the genes from the parents and forming 'Tt'. As the 'T' gene is dominant, all the plants of F, generation will be tall.

In F_1 hybrid tall (Tt), both the dominant as well as recessive factors are separated from each other in the gametes. So in each heterozygous pea plant two types of male gametes bearing 'T' and 't' and two types of female gametes bearing 'T' and 't' are formed in equal numbers. In F_1 self-pollinated plants, the male gametes are randomly united with female gametes; after self-fertilization four possible combinations are formed in F_2 , such as TT, Tt Tt and tt. As the 'T' is dominant over the 't' so the TT, Tt and Tt combinations will express their tallness and tt will be dwarf due to presence of double recessive factors. So expressed monohybrid ratio becomes 3:1. 'TT' plants with double dominant will be produced only pure form of tall offspring; Tt and Tt plants will be produced tall and dwarf in the proportion of 3:1 in F_3 generation, just like monohybrid ratio in F_2 and tt plants with double recessive will be produced only pure form of dwarf plants. So in reality the ratio becomes in F_2 , 1 (pure tall): 2 (hybrid tall): 1 (pure dwarf) in genetic combination.

SERIAL NO.	TRAITS	ALTERNATIVES OF 'P' GANERATION	DOMINANT OF F ₁ GENERATION
1	Plant length	Tall × Dwarf	Tall
2	Flower	Axial × Terminal	Axial
3	Seed shape	Round × Wrinkled	Round
4	Seed coat	Coloured (Grey) × White	Coloured (Grey)
5	Cotyledon colour	Yellow × Green	Yellow
6	Pod shape	Inflated × Constricted	Inflated
7	Pod colour	Green × Yellow	Green

Table 3: Table showing Mendel's seven monohybrid crosses in garden pea and the reults in F, generation.

Traits	Alternatives of 'P' generation	No of F, dominants	No of F, recessives	F, ratio (approx. ratio) (Dominant . Recessive)
1. Plant length	Tall × Dwarf	Tall 787	Dwarf 277	2 84 · 1 3 1 Ratio
2. Flower	Axial × Terminal	Axial 651	Terminal 207	3 14 : 1 = 3:1 Ratio
3. Seed shape	Round × Wrinkled	Round 5,474	Wrinkled 1,805	2.96 : 1 = 3:1 Ratio
4. Seed coat	Coloured (grey) × White	Grey 705	White 224	3.15 : 1 = 3:1 Ratio
5. Cotyledon Colour	Yellow × Green	Yellow 6,022	Green 2,001	3.01 : 1 - 3:1 Ratio
6. Pod shape	Inflated × Constricted	Inflated 882	Constricted 299	2.95 : 1 = 3:1 Ratio
7. Pod colour	Green × Yellow	Green 428	Yelfow 152	2.82 . 1 = 3·1 Ratio

Table 4 Showing Mendel's statistical record of monohybrid crosses and derivation of 3:1 ratio.

• Inference from monohybrid crosses: Mendel carried out his monohybrid experiments on the above seven pairs of contrasting characters of garden pea. At the end of each experiment and observation, he came to the same conclusion. The characters are not blended each other rather they remain separate. So an inference is deduced which is known as law of segregation (Mendel's first law).

7.5.2. EXPLANATION OF TERMINOLOGY IN RELATION TO INHERITANCE

The following terms are commonly used in inheritance and for proper understanding of the subject the students should have familiar with the following terminology.

[1] Gene: The term 'factor' that was used by Mendel, now it is known as 'gene'in modern genetics. Gene is an unit particle that control the appearance of a character in an individual during development of zygote and gene is transmitted from one generation

to the next through the nucleus of gamete

[2] Allelomorph or Allele: For each alternative of a character there is a gene. So for two alternatives of a character there are two genes in homologous chromosomes. A pair of genes that represent constructing alternative of a character placed at the same locus in the homologous chromosomes (pairing of two chromosomes) are designated as allelomorphs or in short alleles. As for example, height of a pea plant is one character and its tallness and dwarfness are the alternatives. Gene of tallness is represented by a 'T' letter and its alternative dwarfness is represented by 't' letter in a homologous pairing of chromosomes. During meiotic cell division gametes are formed and they carry one gene of a pair of allelomorphs.

[3] Homozygous and Heterozygous (Hybrid): When both the genes in a homologous pairing are of the same nature of a character that individual is said to be homozygous, i.e. pure form for a character. Such genes are identical in nature. As for example, after fertilization a pair of genes are present in a zygote for a particular character. In case of homozygous pea plant that pair of genes are of same nature in the zygote,

such as TT or tt. Such zygote is known a homozygote.

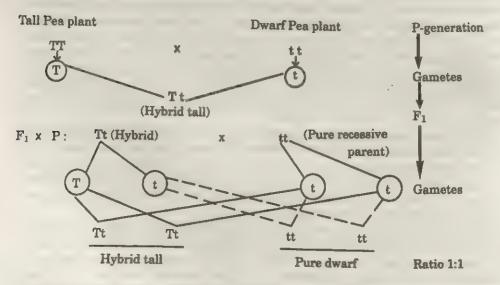
When both the genes in a homologous pairing are of different nature of a character that individual is said to be heterozygous, i.e. hybrid form for a character. Such genes are not identical. As for example, in heterozygous pea plant in relation to taliness and dwarfness, the pair of genes are dissimilar in zygote and form alleles, such as Tt. Such zygote is called heterozygote and the individual develops from this is known as heterozygous.

- [4] Dominant and Recessive: In a heterozygous (hybrid) organism two contrasting genes of a character are present. Only one gene of the alleles is able to produce of a particular character while the other gene is unable to do anything. The gene which can express its character is known as dominant gene and the character is known as dominant character. The gene which is unable to express itself is known as recessive gene and the character is known as recessive character. In case of dominant gene, the first letter of the dominant character is written in capital form; While in recessive gene generally small letter of the dominant character is written. For instance, in heterozygous garden pea plant the gene for tallness becomes dominant as they are tall and so the gene is represented by 'T' (capital letter of dominant character) while the gene for dwarfness bocomes recessive as it is unable to express and so the gene is designated as 't' (small letter of dominant character).
- [5] Phenotype and Genotype: Characteristics of an organism that are visible externally constitute its phenotype, i.e. result of the sum total of reaction between the genes and the environment. Phenotype does not include the characteristics that are not expressed by recessive gene.

Entire genetic costitution of an individual is known as genotype. Dominant and recessive both the types of genes are included in the genotype, i.e. both expressed and unexpressed characters. As for example, on the external point of view all the pea plants of F₁ generation are tall and this tallness is phenotypic but genotypically they are not pure tall (hybird), because their genotype is Tt.

[6] Test cross: When any one of the F₁ hybrid plants is crossed with a recessive homozygous parent then it is known as test cross. In this cross 50% will be hybrid type and 50% will be recessive type in the ratio of 1:1 and this will happen as the two contrasting alternatives become segregated in equal numbers. This test cross is also used to verify the homozygosity of the recessive parent as well as the validity of factor hypothesis or gene theory.

As for example-



Mendel made such crosses in pea plant and he observed 1:1 ratio in the offsprings. Table 5: showing 1:1 ratio in offspring of Test cross.

[7] Back cross: When any of the hybrid plants is crossed with either of the parental generation then this type of hybrization is called back cross. This type of crossing is also devised by Mendel. Plant and animal breeders, made such back crosses only to inprove the breeds and varieties of animals and plants.

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7.5.3. DIHYBRID CROSS

Definition: A cross between the two parents havong contrasting pairs of two traits is known as dihybrid cross.

Description of the experiment: In a dihybrid experiment, Mendel selected a pear plant having a pure yellow cotyledon and round shaped seeds and the other selected plant having a pure green cotyledon and wrinkled shaped seeds. Now he cross-pollinated between the two selected plants of 'P' generation, *i.e.* the pollen grains of one are artificially transferred to the stigma of the other plant. After cross fertilization all the seeds were yellow and round. They were designated as \mathbf{F}_1 generation, *i.e.* in \mathbf{F}_1 generation all the seed shapes were round with yellow coloured cotyledon.

F₁ plants were allowed for self-pollination, as a result self-fertilization occured. Due to self fertilization four types of seeds were developed and were treated them as F₂ generation. Among the four types of seeds, he found both the parental combinations as well as new combinations, such as the parental types yellow and round seeds, green and wrinkled seeds; new combinations (recombinants) are yellow and wrinkled seeds, green and round seeds Mendel examined a total of 556 seeds of F, plants and observed [i] 315 seeds yellow and round. [ii] 101 seeds yellow and wrinkled, [iii] 108 seeds green and round and [iv] 32 seeds green and wrinkled. So he deduced the ratio as 9:3:3:1. Below a chart is given on the basis of the above dihybrid experimentation.

'P' generation : Pure yellow and Round seed plant × Pure Green and Wrinkled seed

plant.

CROSS POLLINATION

F, generation: Yellow and Round

F₂ generation Yellow and Yellow and Green and Round Wrinkled Round Wrinkled

9 3 3 1

So the ratio 9:3:3:1

Table 6: Showing the phenotypic ratio in dihybrid cross.

Explanation of the experiment :

As the seeds of F₁ generation are all Yellow and round, so it can be assumed that Yellow is dominant over the green and round is domonant over the wrinkled. Now the factors or genes are represented here by symbols. As the yellow and round are dominants so the yellow and round are represented by capital letters Y and R respectively. So the genetic combination of pure yellow and round plant of parental (P) generation will be YY RR; pure green and wrinkled plant of parental generation will be yyrr. During the formation of male and female gametes of yellow and round plant, the gametes will carry YR and so the gametes are of one type, similarly in green

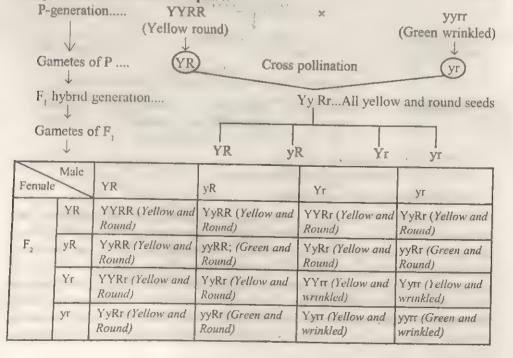
and wrinkled plant, the gametes will carry **yr** and gametes are also one type. After cross-fertilization the zygotes will carry YyRr and the genetic combination in the seeds of F, hybrid will be **Yy Rr**.

F₁ hybrid plants will produce male and female gametes. During the formation of gametes in meiotic cell division one pair of alleles Yy will be separated into Y and y, another pair of alleles Rr will be separated into R and r. These four genes combines independently in such a way that each gamete contain one gene for seed shape and one gene for cotyledon colour, i.e. Y gene can combine with R gene or Y gene can combine with r gene and in the same way y gene combine with R gene or y gene can combine with r gene (random combination). Thus F₁ hybrid plants produce four types of male (pollens) and four types of female (ova) gametes in equal proportions, such as male gametes YR, Yr, Ry, yr and female gametes YR, Yr, Ry, yr. This is possible when two genes assort independently and one pair of genes has no influence over the another pair.

Development of four types of male and four types of female gametes in equal proportions can be verified by test cross.

● Test cross: Mendel made a test cross between a hybrid plant of F₁ generation with that of a double recessive parent plant. He observed the plants on the following frequencies -31 plants with yellow and round seed, 26 plants with green and round, 27 plants with yellow and wrinkled and 26 plants green and wrinkled. As the green and wrinkled parent plant produces only one type of gametes, so for the development of different kinds of plants in the ratio of 1:1:1:1 definitely indicates that the gametes must be of four kinds (YR, Yr, Ry, yr) in equal proportions.

Now the above four types of male and female gemetes of F_1 generations can combine in various ways to form many kinds of zygotes. The male and female gametes can combine in 16 possible ways and develop the F_2 generation. This can be shown in **chequer board** or **Punnett's square.**



F, phenotypes:

Yellow and Round = 9
Yellow and Wrinkled = 3
Green and Round = 3
Green and Wrinkled = 1

Ratio 9:3:3:1

Table 7: A dihybrid cross between homozygous yellow-round and green-wrinkled seed of pea plant and the F₂ result in chequer board or Punnett square.

ENOTYPE	GENOTYP	IC RATIO PH	ENOTYPIC	RATIO PHENOTYPE
YYRR YyRR	A STATE 1 2		9	Yellow and Round
YYRr ' ' YyRr	2 4			
YYm Yym		}	. 3	Yellow and wrinkled
yyRR yyRr	1 2	}	3	Green and Round
уугт	1	, 113	z 1 °°,	Green and Wrinkled

Table 8: The ratio of Genotype and Phenotype in dihybrid cross in pea plant (Pisum sativum)

• Inference deduced from the experiments:

Mendel studied many other traits in dihybrid crosses in pea plant (*Pisum sativum*) and obtained the similar results. He also made trihybrid crosses and observed the independent assortment of alleles. So a law is deduced from the dihybrid and trihybrid experiments and that is known as **law of independent assortment** which is regarded as Mendel's second law.

7.5.4 EXPLANATION ON THE PRINCIPLES AND LAWS OF MENDEL

After various experimentations on garden pea plants, he laid down certain principles and laws on heredity and these are described below.

- [1] Unit character in inheritance: Characteristic features of living organisms are handed over from one generation to subsequent generations. These characters are controlled by 'factors'. Now these factors are known as genes. Each character or trait is dependent on one pair of factors or genes and the gene is the unit material in inheritance.
- [2] Principle of dominance: Mendel observed that one of the factor of a trait was expressed in the F_1 hybrid offspring and the other was always absent but reappeared in the F_2 generation. The factor that associates with an alternate forms of trait is able to express in the hybrid is known as dominant factor or dominant gene and the character that is expressed is called dominant character. The factor that associates with an alternative forms of a trait is unable to express rather remains hidden in F_1 generation but reappears in the F_2 generation is known as recessive factor or recessive gene and the character that fails to express is called recessive character.
- [3] Law of segregation: Mendel observed that there was no blending or mixing of characters in the hybrids rather they remained separate. So each factor of a pair of alleles is transmitted to the offspring through the gamete. The law of segregation states that during gamete formation, the two factors or genes of a pair of alleles separated or

segregated consequently each gamete contains one factor or gene but the paired form is restored again after fertilization in the zygote. This law is also known as **Mendel's** first law. This law is applicable in all cases.

[4] Law of Independent Assortment: In the dihybrid cross of yellow and green, round and wrinkled seeds, he observed the ratio of 9 (yellow round): 3 (yellow wrinkled): 3 (green round): 1 (green wrinkled). This ratio indicates that the yellow and green appear in the ratio of 12 (9+3): 4 (3+1), i.e. 3:1 ratio. In the same way, the round and wrinkled appear in the ratio of 12 (9+3): 4 (3+1), i.e. 3:1 ratio. It may be noted that yellow and green pair has no influence over the round and wrinkled pair; rather they behave just like monohybrid cross. In other words, two pairs of alleles behave independent to each other. Mendel also observed the similar results in trihybrid cross. From the various experiments of di and trihybrid of pea plant, he formulated the Law of independent assortment states that two or more pairs of alleles are assorted independently of one another during the formation of gametes and recombine in all possible combinations. The law is also known as a Mendel's second law.

7.5.5. REASONS OF MENDEL'S SUCCESS

In the pre-Mendelian period specially in the early part of the 19th century many plant and animal breeders made various types of artificial hybridization experiments. But they failed to deduce any fundamental laws of heredity. Fundamental laws of inheritance for the first time laid down by Mendel in the middle of the 19th century. His wise selection of the experimental material as well as scientific method of study made him success in the duduction of the laws of inheritance.

- [1] SELECTION OF EXPERIMENTAL MATERIAL: Mendel selected the garden pea plant as his experimental material for the following reasons.
- [i] Variations: The organism which is to be chosen for the hybridization experiments should have a number of variations. In this regrad, garden pea plants (*Pisum sativum*) were available in many varieties in nature and Mendel selected only of seven contrasting characters out of the many varieties.
- [ii] Short life cycle: The chosen organism must have short life cycle so that experiments may be continued in the subsequent generations. Mendel selected the garden pea plant because it was an annual plant.
- [iii] Reproductive structures: The organism which is to be chosen for the hybridization experiment should be sexually reproducing one; so that offsprings will be able to receive the characters from both the parents. It this respect, Mendel selected this garden pea plant and the hybridization experiments became easy because its flowers are protected from the influence of foreign pollens where cross-pollination normally does not occur.
- [iv] Hybrid fertility: To study the subsequent generation in the hybridization experiments, the hybrid offspring must be in fertile condition. Selection of pea plant in this respect is quite justified as the artificial cross-pollination is almost successful and the hybrids obtained by crossing of two varieties were perfectly fertile. So Mendel continued his experiments upto the F, and F, generations.
- [v] Production of offspring: For hybridization experiments the chosen organism should produce large number of offsprings, so that it will be helpful in correct deduction.

In analysis of the experiment of pea plant, Mendel came to the correct deduction as it produced large number of offsprings in each generation.

[vi] Easy in handling: The experimental material will be selected in such a way so that it will be less expensive and easy to bred and maintain the race. In this point of

view. Mendel's selection of pea plant was quite correct.

[vii] Contrasting factors: Mendel selected seven pairs of contrasting characters of garden pea plant. He was lucky enough, because all these seven pairs of contrasting factors (genes) were present on separate pairs of homologous chromosomes though he was not aware about the chromosomes and genes.

[2] SCIENTIFIC METHOD OF STUDY: The method of study of Mendel was simple but it was based on logical as well as mathematical analysis. His scientific analysis was quite different from his predecessors in many ways. This new approach of study

most probably laid success in formulating the laws of inheritance.

[i] Particular character: Mendel made hybridization on a particular character and observed the pattern of inheritance in one or two characters at a time. This process of experimentation made the complex problem into simple one. His predecessor hybridists had been concentrating on plants and animals as a whole and studied all variations in the hybrid at a time.

[ii] Experiments upto F_3 : Mendel did not stop hybridization experiments on pea plant upto F_1 generation but carried out experiments upto F_2 and F_3 generations.

- [iii] Keeping Statistical records: Mendel maintained all sorts of records of the various experiments on garden pea plant. Definitely that was the new idea and thought of Mendel in the field of breeding experiments. This statistical record helped him to derive the numerical rations in monohybrid and dihybrid crosses.
- [iv] Back cross and test cross: Whether the expressing phenotypic character in F_2 offsprings is really a homozygous or heterozygous, to verify it Mendel made back crosses, i.e. a cross between F_1 offspring with a pure parental generation. If the F_1 offspring is crossed with a pure recessive parent then the dominant as well as recessive characters will be expressed in equal numbers in the offsprings into 1:1 ratio (1/2 of the offspring with dominant character and 1/2 of the offspring with recessive character). This result shows that the offsprings of F_1 generation are all heterozygous or hybrid. This cross is known as test cross, i.e. to test the homozygosity or heterozygosity in F_1 generation.

7.6. Modern status of Mendelism

Morgan, Muller, Bateson, Sturtevant like renowed geneticists worked on various organisms in the post-Mendelian period. They observed that Mendel's first law, the 'Lawof Segregation' is above criticism; as alleles are never blended in hybrids. Though in some cases the alleles interact to produce a new character. However some complexities have been observed by the present geneticists and these complexities cannot be explained by Mendel's principles. But with suitable modifications, these complexities can be resolved and these are given below.

[1] Incomplete dominance: The complete dominance is not universally observed in all organisms. However, in some organisms certain trait of \mathbb{F}_1 phenotype are not resemble any one of the two parents but the trait becomes intermediate between the parent characters. For example, when four O'clock plants (Mirabilis jalapa) of red

flower are crossed with white flower, all the F_1 offsprings are found to be **pink coloured** flower. So the red colour is not completely dominant over the white colour. The intermediate (midway between the two parents) colour that appears in the F_1 progeny is due to the **incomplete dominance** of the genes. When F_1 hybrids are self-fertilized, the progenies of F_2 become red, pink and white in the ratio of 1:2:1. The red and white coloured flowers are homozygous and pink-coloured flower is heterozygous. But incomplete dominance is not due to the bleeding of the gene of alleles, because the red and white parental characters reappear in the F_2 progenies. So the genes of the alleles are segregated in the subsequent generations but their equal effectiveness are expressed in the hybrids Such incomplete dominance also occurs in Snapdragon (plant), fowl etc.

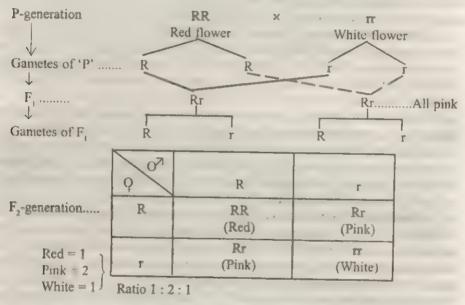


Table 9: Showing in Chequer board the incomplete dominance of flower colour in four o'clock plant (Mirabilis jalapa)

[2] Modifications in Dihybrid Mendelian ratio due to interaction of genes :

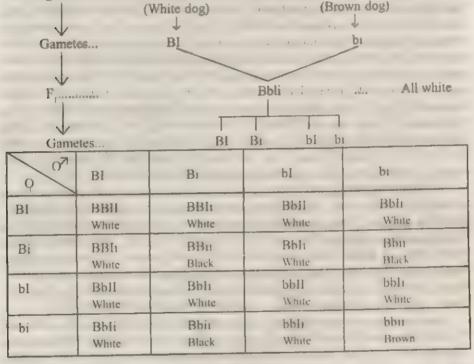
According to Mendel's experimental results, we come to know that a single phenotypic character of an organism is determined by two alleles of a single gene. Out of the two alleles one allele is dominant over the other which is regarded as recessive. This kind of reaction takes place between the two alleles of a gene and this is known as **intra-allelic interactions of gene**. These types of reactions give the typical Mendelian ratios of 3:1 and 9:3:3:1. Subsequently many geneticists made several experiments on various organisms and the results they obtained that could not be explained on the basis of Mendelian inheritance. They observed that instead of single gene single character hypothesis, many genes affect the single character. So the many genes that located on different chromosome pairs interact with one another for the expression of a single phenotypic character of an organism. This is known as **inter-allelic interactions of genes** that locat to modification in basic Mendelian ratios. A few modifications due

to interaction of genes are given below.

P-generation...

[a] Epistasis (Greek word Epistasis means standing upon). Some time it occurs that two independent genes affect the same character of an organism and expression of one gene hides or covers the effect of other gene. In other words, one gene does not allow the other gene to express itself. The effect of masking or hiding of one gene by another gene is known as epistasis. The gene that masks or prevents the action of another is known as epistatic gene and whose expression is suppressed is said to be hypostatic gene. This phenomenon should not be confused with dominance. The epistasis is the interaction of two separate genes while the dominance is the interaction of two alleles of the same gene. Epistatic interaction between genes is the cause of diviations from the Mendelian dihybrid ratio.

BBII



F, Phenotype

Table 10: Chequer board showing the modified ratio of 12 s 1 due to epistasis instead of Mendelian dihybrid ratio of 9:3:3:1

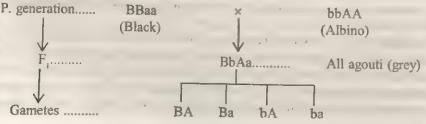
In dog the coat colour is depending upon the action of two genes. There is a pair of alleles B and b of a gene for coat colour. 'B' produces black colour and 'bb' produce the brown colour. There is also a pair of alleles I and i of a gene which controls the development of pigment in the coat. The dominant allele I prevents the expression of coat colour even though the specific B and b gene for colour is present. The alleles of

hypostatic gene such as BB, Bb or bb, express the character only whem two recessive alleles it occur on the epistatic locus, *i.e.* BBit or Bbn produces black colour and bbn produces brown colour. Now a cross is made between a homozygous white dog with a homozygous brown dog.

It is clear from the chequer board that out of 16 offsprings, twelve are white due to presence of dominant epistatic gene, three are black due to presence of dominant hypostatic gene and absence of dominant epistatic gene, one is brown due to absence of both dominant epistatic and hypostatic gene. Epistasis also occurs in relation to colour of fowls, mice, flower colour in squash etc.

- [b] Complementary genes (9:7): This is another kind of interaction of genes where both the genes are essential for the expression of a particular character such genes are known as complementary genes. In this case, each pair of alleles of genes are located in separate chromosome pairs and the one pair of alleles is determiner and the other pair is initiater. In sweet pca (Lathyrus odoratus), one dominant allele of a gene in flower colour acts as a determiner that helps to develop a colourless substance chromogen and another dominant allele of a gene acts as an initiater that helps to activate an enzyme that transforms the chromogen to coloured substance. So these two genes are regarded as complementary genes. W. Bateson and R.C. Punnett observed that when two white flowered sweet peas were crossed, all the progeny of F_1 were coloured. When F_1 were selfed then they produced 9 coloured and 7 white in F_2 generation (9:7 ratio) instead of Mendel's dihybrid ratio of 9:3:3:1. Bateson explained this phenomenon that this cross is involved with two pairs of alleles of two genes and they are complementary to each other in relation to expression of chatacter, so it is really a dihybrid cross which is a modification of dihybrid ratio of 9:3:3:1
- [c] Supplementary genes (9:3:4): When two independent but dominant genes interacting in such a way that a different type of phenotypic expression is developed and these genes are known as supplementary genes. As for example, the hair colour in the mouse also depend on the interaction of a number of genes. When black mice is crossed with an albino (white), hybrids are of the grey colour or agouti (individual hair is grey with yellow). This agouti colour pattern is the wild ancestral type. When F₁ agouti individuals are crossed among themselves, the F₂ generation consists of agouti, black and albino, in the ratio of 9:3:3:1.

These results can be explanined by assuming that the black parent mice contain a 'B' gene which controls the black colouration of the hair and the albino (white) parent mice contains 'A' gene which controls the albino colouration of hair. In the hybrids, both the A and B genes are present and due to the interaction of these two dominant genes, the colour of the hairs become agouti (grey). But in absence of any one, there will be no agouti colour. So B and A genes are regarded as supplementary genes. This can be shown in the **chequer board**.



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	Gamete's	97	ВА	Ва	bA	ba
Γ		BA	BBAA (Agouti)	BBAa (Agouti)	BbAA (Agouti)	BbAa (Agouti)
	F ₂	Ba	BBAa (Agouti)	BBaa (Black)	BbAa (Agouti)	Bbaa (Black)
l		bA	BbAA (Agouti)	BbAa (Agouti)	bbAA (Albino)	bbAa (Albino)
		ba	BbAa (Agouti)	Bhaa (Black)	bb∧a (Albino)	bbaa (Albino)

Phenotypic ratio—9 (Agoutt): 3 (Black): 4 (Albino)

Table 11: Checker board showing the modified ratio of 9.3.4 due to interaction of supplementary genes instead of Mendelian dihybrid ratio 9:3:3:1.

Thus the Mendelian dihybrid ratios are modified in various ways. In hybridization, new and different combinations are produced due to the interactions between the genes. At present nearly all types of inter-allelic genetic interactions are treated as epistasis.

[3] Multiple Alleles: In the cases of inheritance dealt with by Mendel, a given locus in homologous chromosomes was occupied by two alternative forms of a genes that influence the same trait. Such different forms of the same gene are known as 'alleles'. However certain genes have more than two allelic forms. They are produced by repeated mutation of the same gene in different directions. In such cases, the various allelic forms are collectively known as multiple alleles. Regardless of their total number, only two members of a set occur in a diploid cell and only one in a gamete. So multiple alleles are detected in a population.

Definition: Three or more kinds of alternative forms of a gene which occupy the same locus in homologous chromosomes are referred to as multiple alleles.

Example of Multiple Alleles: In Rabbit, coat-colour is controlled by a series of four alleles. In *Drosophula* (Fruit fly) eye-colour is controlled by a series of fourteen alleles. A well known example of multiple alleles is the inheritance of ABO blood groups in man.

Human blood groups are classified on the basis of the type of glycoproteins known as agglutinogen or antigen, found on the surface of the RBC. Glycoproteins (antigens or agglutinogens) are of two kinds and they are represented by letters A and B. If A glycoprotein (antigen) is present, the blood group is known as A; if B glycoprotein (antigen) is present, the blood group is known as B; if A and B both the glycoproteins (antigenes) are present, the blood group is known as AB and if A and B both the glycoproteins (antigens) are absent, the blood group is known as 'O'. Hence human blood groups are classified into four categories.

These four catagories of blood groups in human population are controlled by a set of three alleles. The allele which produces glycoprotein (antigen) A is represented by L^A ('L' is used to honour Landsteiner who discovered the human blood groups), the allele which produces glycoprotein (antigen) B is represented by L^B and the allele for absence of both glycoproteins (antigens) is represented by L^C. Alleles L^C and L^C are both dominant over allele L^C. Any person will carry only two of the three alleles, i.e. one from each parent. However, with these three alleles, it is possible to get six genotype and four phenotype combinations.

Table 12: Showing genotypes of four blood groups.

Blo	od group (Phenotype)	Genotype
1. 2. 3. 4.	A B AB O	LoLo Ty Ty Ty To Ty Ty Ty To

If parents are both heterozygous for blood groups A and B, then in all the children with all the four types of blood groups are possible.

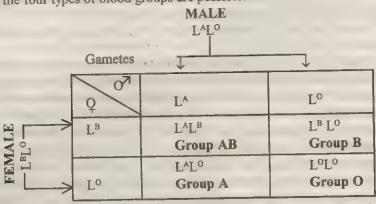


Table 13: Result of a cross between a male heterozygous for blood Group A and a female heterozygous for blood Group B.

The genotypes of the above table indicate that the blood group is also inheritable character and inherited in the simple Mendelian fashion.

Importance of Multiple alleles:

(a) The study of multiple allelism assumes inportance because it sheds some light on the nature of gene. Multiple alleles suggest that a gene can mutate in a number of different ways.

(b) The knowledge of blood groups of the parents can provide infomation about the

possibilities and impossibilities of blood groups of childrens.

(c) The knowledge of blood group also helps to some extent as evidence to settle the cases of disputed paternity.

[4] Multiple gene Inheritance

Two or more different pairs of genes which act in a cumulative way on a trait are known as multiple gene inheritance or polygenic inheritance or quantitative inheritence.

Explanation: Mendel studied Seven pairs of contrasting characters in garden pea (*Pisum sativum*), such as tall and dwarf, round and wrinkled etc. In such experiment no intermediate forms are visible rather the phenotypic differences are distinct and so discontinuous variations are observed. These types of traits where no intermediate forms are known as **qualitative traits** and they are controlled by a pair of genes. Such type of inheritance is known as **monogenic inheritance**.

There are many characters or traits among plants and animals that show continuous variation from one extreme to the other or intermediate forms between the two extermes. Such traits can be measured in terms of quantity and are known as **quantitative traits**. The quantitative traits are controlled by two or more pairs of genes; so traits are produced by the interaction of multiple genes; such type of inheritance is known as multiple

N

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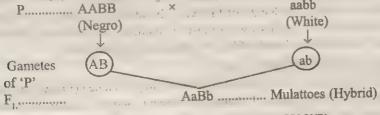
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gene inheritance or polygenic inheritance. Hence certain traits are quantitative instead of being qualitative. Among the quantitative traits in animals, the characters like variations of skin colour with all intermediate forms in human beings, variations of eye colour in *Drosophila* are produced by the additive action of multiple genes. Variations in plants may also seen in traits like seed size of beans, grain colour in wheat are also controlled by multiple genes, as a result continuous variations occur in F₂.

Example: A common example of multiple gene inheritance is observed in skin colour of human beings. This is first observed by C.B. Davenport in 1913. Davenport assumed that the skin colour of Negroes differ from the Whites in having two pairs of genes (pigment forming) and they do not show dominance, *i.e.* this trait is controlled by two pairs of genes. But many investigators have estimated 2 to 20 pairs of genes that control the colour of human skin. Though pigmentation of skin can be easily influenced by the environmental factors also.

When the pure Negro (AABB) and pure White (aabb) races cross, they produce a hybrid of genotype AaBb. The individuals of F_1 generation (hybrid) are known as mulattoes and the colour of their skin will be intermediate between the parents. When F_1 individuals intermarry among themselves, all shades of skin colour are obtained in F_2 generation which-shown in the Checker board. Hence the inhiritance of pigmentation of skin in man is mainly due to the action of many genes which have no dominance but with cumulative effect. In brief, if the F_2 individuals are clssified according to the number of genes for black they possess, the number of individual in each group is expressed by the ratio 1:4:6:4:1.



(INTERMEDIATE SKIN COLOUR)

AaBb × AaBb F, Intercross

Gametes OF F,

POP	AB	Ab	аВ	ab
AB	AABB (Negro Skin)	AABb (Darker than Mulattoes)	AaBB (Darker than Mulattoes)	AaBb (Mulattoes)
Ab	AABb (Darker than Mulattoes)	AAbb (Like Mulattoes)	AaBb. 15.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6	· Aabb (Lighter than Mulattoes)
aB	AaBB (Darker than Mulattoes)	AaBb (Like Mulattoes)	aaBB (1.11) (Like Mulattoes)	aaBb (Lighter than Mulattoes)
ab	AaBb (Like Mulattoes)	Aabb (Lighter than Mulattoes)	aaBb (Lighter than Mulattoes)	aabb (White Skin)

Frequency of F, progeny:

Negro skin colour	Skin Colour between Negro and Mulattoes	Skin Colour of Mulattoes	Skin colour between White and Mulattoes	
1/16	4 16	6 16	4/16	$\frac{1}{16}$

Table 14: Showing the inheritance of skin colour in F₁ and F₂ from a cross between a Negro and a White man.

[5] Pleiotrophism:

- Definition: When a single gene influence the expression of two or more visible characters simultaneously of an organism, it is called pleiotropy and this phenomenon is known as pleiotropism.
- Explanation: We have seen in many cases where one gene control the expression of a single phenotypic character. This One gene-one trait hypothesis does not explain all types of inheritance. On the other hand, sometimes more than one gene i.e. multiple genes are interact to influence the expression of a single phenotypic character. In the living organisms, it has been observed also that a single gene regulates many phenotypic characters; such a gene is called pleiotropic gene.
- Example: Careful studies have revealed that a large number of pleiotropic genes are present in many organisms, such as *Drosophila*, Rat, Man etc.

For instance, in *Drosophila*, a mutant pleiotropic gene is generally known as wing gene which mainly controls the length of the wing. In addition, it further produces other effects also; such as it changes wing muscles, modifies the balancers, rate of growth, shape of spermatheca, length of life, makes certain bristles erect.

[6] LINKAGE AND CROSSING OVER

Gregor Mendel studied the seven pairs of characters in garden pea (Pisum sativum) and the factors for the seven pairs of characters showed random assortment during gamete formation. The term factor was subsequently replaced by Johannsen in 1909, with the term gene. In the dihybrid experiment of gardian pea, Gregor Mendel deduced the 'law of independent assortment'. Law of independent assortment states that when two or more factors are considered together then these factors show independent and random assortment during distribution into the gametes. Mendel was lucky enough that the seven pairs of alleles are present in the seven different homologous pairs of chromosomes. It is therefore necessary that if the two pairs of alleles have to assort independently then these alleles should be located on two separate homologous chromosomes. Subsequently it has been discovered that when two or more than two genes are situated on the same homologous pair of chromosomes then the independent assortment of genes will not occur. Rather they have a tendency to inherit together, i.e. show linkage. Some times exchange of segment occurs between the two non-sister chromatids of homologous chromosome during the prophase I of meiosis; as a result, recombinant types also occur. These two phenomena of linkage and crossing over will be discussed below.

[A] LINKAGE:

(i) **Definition**: Linkage can be defined as the tendency of genes to remain together during the process of inheritance due to presence on the same chromosome.

It has been cytologically proved that a single chromosome bears many genes. All the genes on the same chromosome are known as linked genes.

(ii) Discovery of linkage:

W. Bateson and R.C. Punnett was first reported in 1906 that a cross in sweet pea (Lathyrus odoratus) shows a deviation to the phenomenon of independent assortment of two genes. They crossed a variety of blue flower colour (B) of sweet pea and long pollen grains (L) with another variety of sweet-pea having red flower colour (b) and round pollen grain (l). Here blue flower is dominant over red flower colour and long pollen grains is dominant over round pollen grain. All the F₁ offsprings are blue flowers and long pollen grains and the genotype of all individuals are BbLI. This is shown in the following cross.



Table 15: Showing a cross between sweet pea plants having Blue flowers, long pollen grains and red flowers, round pollen grains.

Now F₁ Individuals with genotype BbLl are crossed with double recessive parentyle type (bbll) which is a test cross. According to independent assortment the expected results in the test cross will be four types of phenotypes in the ratio of 1:1:1:1 *i.e.* equal number of offsprings. But this was not happened. The four phenotypes were actually obtained in the ratio of 7 (Blue long): 1 (Blue round): 1 (Red long): 7 (Red round). The greater number of the parental forms and the lesser number of recombination types indicated that the two genes do not assort independently. This is shown in the following test cross.

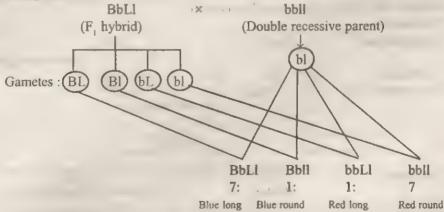


Table 16: Showing the Test cross between F, hybrid and recessive parent.

Bateson and Punnett concluded from their experiments on sweet pea that alleles which come from the same parent tend to enter the same gamete. This phenomenon was referred to as coupling phase; while those alleles of different parents tend to enter different gametes and this phenomenon was referred to as repulsion phase. So Bateson and Punnett explained the deviation from independent assortment in their

experiments by means of a hypothesis known as 'Coupling and repulsion hypothesis'.

Later Morgen in 1910 made similar observations in Fruit fly (Drosophila melanogaster). He concluded from his observation that both coupling and repulsion are two aspects of the same phenomenon. This phenomenon he called Linkage.

(iii) Linkage Groups:

Several genes are located in the same chromosome and they are arranged in a linear order. All the genes located in the same chromosome have a tendency to inherit together due to force of attraction amongst them. These genes are called **linked genes**. The strength of linkage between two genes is proportional to the distance between the genes in the chromosome. All the genes on a chromosome are linked with one another form a linkage group. As the homologous chromosomes posses either same genes or allelic genes then they form the same linkage group. Hence the number of linkage groups in an individual animal or plant corresponds to the number of pairs of chromosome present in the cells or to its haploid chromosome number. This is known as limitation of linkage groups. Thus in Fruit fly (*Drosophila melanogaster*) there are 4 pairs of homologous chromosomes or 4 haploid chromosomes and so 4 linkage groups are present. The garden pea (*Pisum sativum*) has seven pairs of homologous chromosomes or 7 haploid chromosomes and so 7 linkage groups are present. Man (*Homo sapiens*) has 23 pairs of homologous chromosomes or 23 haploid chromosomes, so 23 linkage groups are available.

(iv) Types of Linkage:

Two types of linkage are observed in animals and plants, such as (a) complete linkage and (b) incomplete linkage.

(a) Complete Linkage: When the two genes are closely located on the same chromosome and there is no crossing over of the genes which are inherited together then only the parental or non-cross over type of offsprings are produced. This phenomenon is known as complete linkage. This phenomenon is very rare yet in *Drosophila* male insect shows this phenomenon.

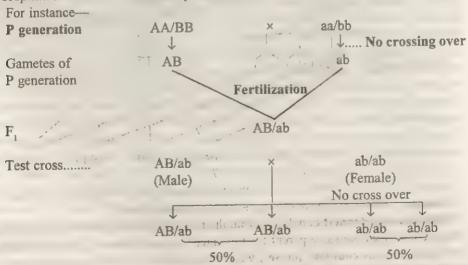


Table 17: Here F_1 (AB/ab) is used as male and test crossed with ab/ab as female (double recssive). We got only two types of progenies (AB/ab and ab/ab) in the next generation with 50% and 50% $te^{-100\%}$ parentals. So the two genes are transmitted intact as a complete linkage.

(b) Incomplete linkage: Generally crossover takes place in few cells between homologous chromosomes even when the two genes are closely situated. This phenomenon is known as incomplete linkage. Here there is a clear case of predominance of parentals or non-cross over types of offsprings than recombinants.

• For instance:

In an ordinary normal fly of *Drosophila* has grey body (G) and long wings (L). A stock is prepared having recessive mutations of black body (g) and vestigeal wings (l), both in the same chromosome. When a pure grey body and long wings (GG/LL) is crossed to a black body and vesigeal wings (gg/ll), the gametes of the two parents combine, giving F₁ offspring of genotype GL/gl and phenotypic character of grey body,

long wings (Hybrid).

Now a female fly from F₁ generation is test crossed with a double recessive black body and vestigeal wing (male), there will be two situations. First, the chromosomes might come together and then separate without cross over between loci g and l, giving eggs of the two non-crossover types such as GL and gl. Secondly, there is crossover between loci g and l, giving eggs of the two crossover types such as Gl and gl. It has been observed that the above four classes of eggs after fertilization are giving rise to 82% parentals or non-crossover types and only 18% cross-over or recombinants. This suggests that this is a clear case of linkage and the type of linkage is incomplete. This can be represented diagramatically below:

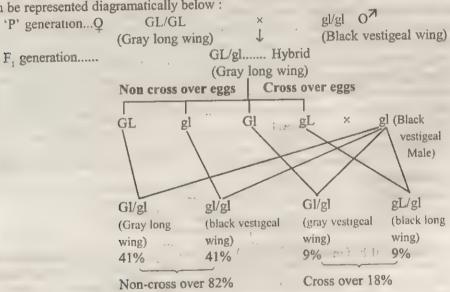


Table 18: Showing incompte linkage in Drosophila (Gray long × Black vestigeal)

(v) Significance of Linkage:

 Linkage checks the appearance of new recombinations so that the specific racial characteristics are maintained in plants and animals.

Linkage helps in bringing the hybrid population resembling to the original parents.

Linkage is also a problem to breeders because linkage does not allow the breeders
to bring the desirable characters in one variety such as, combination of short duration
and high yield could not be achieved in a rice variety.

[B] CROSSING OVER:

(i) Definition: Crossing over may be defined as the phenomenon of interchange of segments between non-sister chromatids of a homologous pair of chromosomes, resulting in a recombination of genes during Prophese I in meiosis.

(ii) Stage at which Crossing over Occurs:

During the zygotene and pachytene stages of the prophese I of meiosis, there is pairing or synapsis between homologous chromosomes. In this pairing, similar parts of the chromosomes remain side by side by mutual attraction between allelic genes. This is known as two-strand stage or bivalent. Further, in diplotene stage of prophase I of meiosis, each chromosome splits longitudinally into two chromatids. Now bivalent is composed of four chromatids. This stage is known as the four-strand stage or tetrad. The chromatids developing from the same chromosome are known as the sister chromatids. Crossing over is detected at four strand stage. It has been observed that crossing over takes place between the maternal and paternal chromatids, i.e. cross over between non-sister chromatids of homologous pairing.

(iii) Example of Crossing over and its results :

Cross over is now illustrated by taking the example of Drosophila melangaster. In Drosophila, two pairs of characters are involved in a dihybrid cross. Mutant fly having recessive characters of pink eyes (r) and curled wings (s) is crossed with a wild fly having dominant characters of red eyes (R) and straight wings (S). In this cross, all the progeny of F, hybrid show red eyes and straight wings having genotype RrSs. Now a female from these F, hybrids is crossed with a double recessive male of P generation which is known as a test cross. This F, hybrid female will produce four types of gametes. When F, female gametes mated with single type of male gametes, the F2 genetation consists of 49% flies with red eyes and straight wings, 49% with pink eyes and curled wings, 1% with red eyes and curled wings and 1% with pink eyes and straight wings.

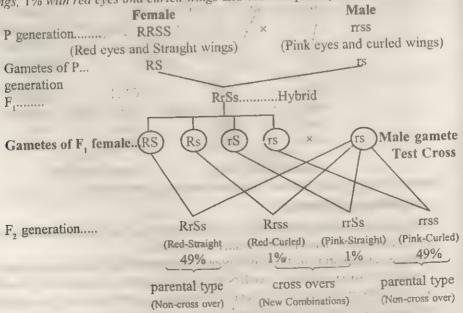


Table 19: Showing crossing over, as a result new-combinations in Drosophila melanogaster

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This result in F, generation shows that the two types are non-cross overs which combine to form 98% and two types of new combinations or reecombinations of the remaining 2% are produced due to crossing over. This experiment shows that both the genes for each allelic pair are situated in the same chromosome. They linked together in 98% gametes having no chromosomal interchage but in the remaining 2% gametes there is interchange between their non-sister chromatids of the homologous chromosomes. This interchange of segments of chromatids occurs due to crossing over.

If the allelic pairs were completely linked and no interchange then only the 100% non-crossover P generation types appeared in F, generation. On the other hand, if the allelic pairs were in separate pair of homologous chromosomes then four types of progeny would have been appeared in equal numbers after the Test-cross. So we can say that the two types of new combinations appear due to crossing over between the homologous chromosomes during meiosis I.

(iv) Mechanism of Crossing Over: The mechanism of crossing over during prophase I of meiosis can be explained by Chiasma-type theory. Then what is chiasma? The point where the non-sister chromatids of a homologous chromosomes are forming a cross-like cofiguration is known as Chaiasma (pl. Chiasmata). The number of chiasmata varied from 1-5 or more. According to this theory the homologous pairing occurs during first prophase. Now each chromosome consists of two chromatids. So four chromatids (four strand stage or tetrad) are formed. Out of the four, only two non-sister chromatids of a homologous pairing are participating in the formation of chiasma. At each chiasma, two chromatids break and then rejoined. As a result of rejoining, there is an exchange of non-sister chromatid segments from homologous chromosomes. This physical exchange between the non-sister chromatids causes the rearrangement of genes. Thus new-combinations arise in the progeny (See Fig. 7.3).

(v) Types of Crossing Over:

Depending on the number of chiasmata of the homologous chromosomes, crossing over may be of 3 types, such as single crossing over, double crossing over and multiple crossing over.

1. Single Crossing Over: Here only one chiasma is formed between the non-sister chromatids; as a result single crossing over occurs. Resultant effect is, two parental types and two recombination types. This single crossing over is very common

2. Double Crossing Over: Here two chiasmata are formed. Hence two crossing over occur at two points in the same tetrad. This type of crossing over is less frequent.

3 Multiple Crossing Over: Here three or more chismata are formed in the tetrad. Corresponding to the number of chiasinata, crossing over occur; though this type does not occur frequently.

(vi) Significance of Crossing Over:

Crossing Over is a wide spread phenomenon in plants and animals. Hence this phenomenon is of great inportance in Genetics. Significance of crossing over is given below:

(a) Crossing over provides a direct evidence that the genes are arranged in a liner fashion

on the chromosome.

(b) Crossing over helps in tracing of linkage groups.

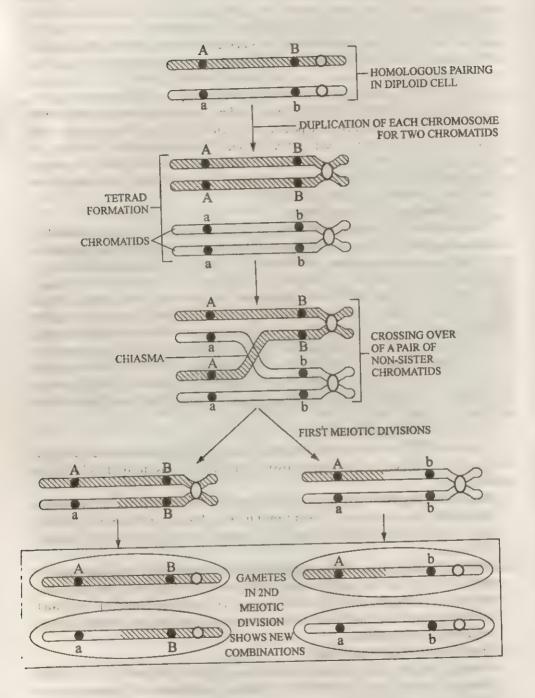


Fig 7.3: Showing formation of Chiasma and recombinant types.

- (c) Percentage of crossing over helps in the construction of chromosome map.
- (d) This phenomenon gives rise to new combination of genes; as a result variations occur in the offsprings. Variation is an essential feature of evolution.

[7] Chromosome Mapping:

(i) Definition: A chromosome map is a line on which the genes are represented by points that are separated by distances proportional to the amount of crossing over. The chromosome map is also known as genetic map or linkage map. Since a chromosome map is based on the percentage of crossing over between genes, it is sometimes known as a crossing over map.

(ii) Explanation: The amount of crossing over, on which the chromosome map is prepared, has been drawn from Test crosses. There is no direct microscopic examination of the chromosome. The chromosome map is based on two assumptions:

(a) The genes are arranged in a liner fashion on the chromosome.

(b) That the perecentage of crossing over between the two genes is an index of their distance in the chromosome.

The frequency of recombination or cross over value is determined as follows:

Recombination frequency or Cross over value =

Total number of recombinants in Test Cross Total number of progeny of the Test Cross

The value is generally represented as a percent of the total population. The variation in recombination frequency is governed by the distance between the genes. Closer the distance between the two genes, the less are the chances of crossing over. As a result, there is lower frequency of recombination. The greater is the distance between the genes, the higher is the percentage of crossing over between them. But there are possibilities of double or multiple crossovers if there is greater distance between the two genes.

(iii) Construction of Chromosome map: To construct the Chromosome map of an animal or plant, its chromosomes are first represented by straight lines and then the positions of genes are determined from the percentage of crossing over data. Then the genes are marked on the chromosome. The unit of crossing over is termed as 'morgan' to show honour of Morgan's contribution. A recombination frequency of 0.01 or 1% cross over occurs between two genes, the genes under consideration are said to be 1 map unit distance, now referred to as 1 centimorgan (cM) apart.

The percentage of crossing over is governed by the distance between the genes concerned. If the two genes are closer then the chance of crossing over will be less which will be reflected in the recombination frequency. Hence the recombination frequency suggests the relative distance between the genes on the chromosome. Now

let us take up a concrete Example:

Genes for yellow body (y), vermilion eyes (v) and miniature wing (m) are linked in the X chromosome of Drosophila. All these three genes are recessive mutants. Genes are linearly arranged on the chromosome and the distances between the genes are additive. Here the map distance between y (yellow body) and v (vermilion eye) is 32.2% and between y (yellow body) and m (miniature wing) is 35.5%. The position of the three genes can be mapped on above data. There are two possibilities in the order of genes, such as map distance between v and m may be 67.7% unit which is the sum of the map distances between y and m (35.5% unit) + y and v (32.2% unit) or it will be 3.3% map distance (35.5%—32.2%) between v and m.

Experimental data reveals that the actual percentage of recombination frequancy is

3.3 between v (vermilion eye) and m (miniature wing). Thus the position of m is on hte right side of v. Thus, in order to add a new gene to the map, we can do so by finding its distance from at least two other known genes on the chromosome map. In *Drosophila*, the positions of various mutant genes have been located in the four chromosomes and maps are prepared. Chromosome maps have also been done in Maize and Chicken.

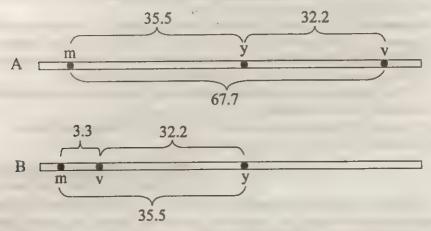


Fig. 7.4: Showing positions of three genes on the X Chromosome of Drosophila melanogaster.

(A) Positions of three genes are incorrect, (B) Positions of three genes are correct on chromosome mapping.

(iv) Factors Affecting Chromosome Mapping:

Many factors are affecting the accuracy of Chromosome mapping. These are given below.

- (a) Double Crossing Over: This phenomenon occurs between two genes which are situated by long distance on the same chromosome. It has been observed, though there is double crossing over yet the two genes are remaining on the same chromosome. There is no apparent sign of crossing over. So calculation of crossing over percentage may cause mistakes in the chromosome map.
- (b) Interference: One chiasma may interfere to form another chiasma formation in the vicinity. As a result, one crossing over may reduces the crossing over in the vicinity.
- (c) **Temperature:** High and low temperatures increase the frequency of crossing over. Hence the temperature causes fluctuations in the location of genes on chromosome.
- (d) X-ray: This ray increases the frequency of crossing over and disturb the location of genes on chromosome mapping.
- (e) Age: Experiment of Bridges shows that crossing over is more frequent in older females of *Drosophila*. Thus age also affects the frequency of crossing over. Hence aging also cause fluctuations in loci of genes on chromosome.
- (f) Location: Crossing over is less frequent near centromere and near the terminal ends of chromosome.
- (g) Sex: The males of many organisms show less frequency of crossing over. In male *Drosophila* there is no crossing over. Thus sex may also affect the frequency of crossing over.
- (v) Utility or Importance of Chromosome Maps:
- (a) Chromosome maps are very useful in the study of genetic engineering.

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(b) Chromosome maps are very helpful to find out the exact location of new mutant gene in chromosome.

(c) Chromosome maps have established the validity that genes are arranged in a linear

fashion in chromosome.

(d) Chromosome maps have established the concept that the specific genes occupy the specific loci in the specific chromosome.

7.6.1. SEX-LINKED INHERITANCE

(i) **Definition**: The genes which are located in the sex chromosome and are transmitted from one generation to the next generation, are known as sex-linked genes and the phenomenon is known as sex-linked inheritance.

(ii) Discovery: Sex-linked inheritance was first discovered by Thomas Hunt

Morgan in 1910 in a tiny insect, Drosophila melanogaster.

(iii) Explanation: A pair of chromosomes which determine the male and female sexes are known as sex chromosome. The remaining chromosomes of a diploid cell are called the autosomes. In Drosophila, man etc. the homologous pairing of sex chromosome in female has two X-chromosomes (i.e. XX) and the male has one X chromosome and one Y chromosome (i.e. XY). In man, the total number of chromosomes in a diploid cell are 46. In a male member, there are 44 autosomes and one pair XY sex chromosomes. In a female member, there are 44 autosomes and one pair XX sex chromosomes. On the basis of sex chromosomes in male two kinds of sperms are produced. At the end of meiosis, half the sperms will carry an X and the other half a Y. Hence the male is heterogametic sex. The female is producing one kind of ovum, i.e. all the ova are carrying X chromosome only. Hence the female is homogametic sex. So we can say that the sex of the child depends upon the kind of sperm (X or Y) that fertilizes the ovum.

Sex chromosomes though determine the sex (male or female) yet there are many other genes in the sex chromosome. The Y chromosome is genitically inert compared with the X-chromosome. The sex-linked genes are present mostly in the X chromosome. Hence a male that carries a single dose of recessive sex-linked gene shows its effects in

the phenotype.

(iv) Examples of sex-linked inheritance in man:

A number of sex-linked traits have been observed in man. Of these, colour blindness and haemophilia are among the important sex-linked recessive traits. We shall now discuss in the following pages two best known sex-linked inheritance in man.

I. COLOUR BLINDNESS: This is a vision defect. Here the eye fails to distinguish between red and green colours. The normal gene and its recessive allele which are controlling the vision are located on the X chromosome. The gene for the normal vision is dominant over its allele for the defect. In males, colour blindness appears in the presence of single recessive gene; because Y chromosome does not carry any gene for colour vision. In females, the colour blindness appears when both the XX sex chromosomes carry the recessive gene. When the females carry single gene for colour blindness and the other gene for normal vision then the females have normal vision. This type of female is treated as carrier.

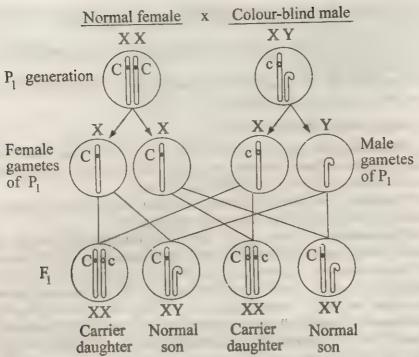


Table 20. Showing the pattern of inheritance of Red-Green colour blindness in male and female human being. Here the females are phenotypically normal but genotypically carriers and the males are normal both phenotypically and genotypically.

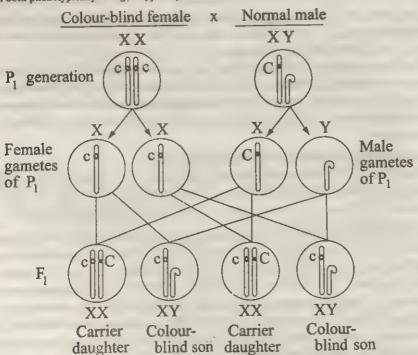


Table 21: Showing the males are colour-blind and the females are carrier. The females are derived their X-chromosome from father (male) and males from mother (female).

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To find out the mechanism of sex-linked inheritance, let us assume that capital 'C' stands for normal gene and small 'c' stands for recessive colour blind gene on the X-chromosomes. If a normal female (CC) is mated with a colour-blind male having 'C' at X-chromosome, in F₁ all the males are normal but all the females are carrier (Tab. 20). If a colour blind female (cc) is mated with a normal male (C) then in F₁ all the sons (male) are colour blind; because sons' X-chromosome derived from their mother (female). All the daughters (female) though normal vision but they are carriers of colour blind gene. Because the daughters receive their dominant gene 'C' from their father (Tab. 21). If a carrier female mated with colour-blind male, then the offsprings will be colour blind daughter and carrier daughter but the sons will be colour blind and normal vision. In the same way, if a carrier female is mated with normal male, then some of the daughters will be normal vision and some of them carrier; in case of male some of them with normal vision and some are colour blind sons.

Hence in all four possible mixed matings, it is clear that the males are more suffer in colour blidness rather than females. This is the fact in other sex-linked inheritance. The trait is transmitted in a criss cross fashion.

II. HAEMOPHILIA: It is also known as bleeder's disease in man and in this disease the patient will continue to bleed from a minor injury or cut. The cause of this disease is due to lack of plasma thromboplastin which is required for coagulaion of blood.

Haemophilia follows the same mode of inheritance as colour blindness in man. It is caused by a recessive sex-linked gene in X-chromosome. Suppose, a heamophilic male married to a normal female, produces carrier daughters and normal son. On the other hand if carrier female married to a normal male then half the daughters are normal and the other half the daughters are carriers; incase of sons, half will be normal and other half will be haemophilic son (Tab. 22)

(v) Characteristics of Sex-linked Inheritance:

From the above crosses of both the colour blindness and the haemophilia, the following characteristics of sex-linked inheritance may be drawn:

- (a) Colour blindness and Haemophilia both are more common in males than in females. Because these defects are caused by single gene in males and double genes in females (sex-linked recessive homozygous).
- (b) In both the cases, males are never carriers because in Y-chromosome corresponding allele is absent. But the females are carriers.
- (c) Type of inheritance is a criss cross pattern, i.e. male transmit the recessive sexlinked gene to the female offspring who inturn transmit it to the male.
- (d) Females transmit the allele of the trait to both male and female offsprings.

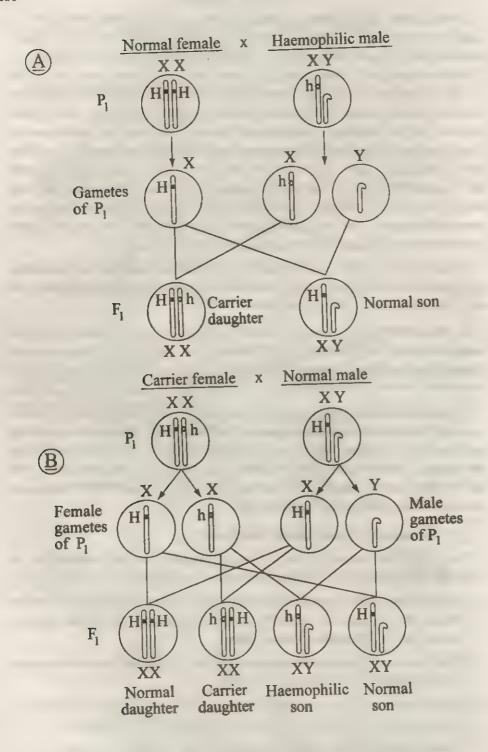


Table 22. Showing the inheritance of haemophilia in man (A & B)

7.7. Mutation

(1) **Definition**: Mutation can be defined as an event that gives rise to a heritable alteration in the structure of a gene or chromosome or a change in chromosome number. The organism in which mutation occurs is known as a mutant.

The term 'mutation' was first introduced by Hugo de Vris, a Dutch botanist in 1901. He observed the sudden variations in the plant, evening primrose (*Oenothera lamarckiana*) and this sudden variation is called mutation by him.

(ii) Types of Mutation:

Mutations are divided into two major types-

- (A) Gene alternation or Gene mutation or Point mutation.
- (B) Chromosomal alteration or Chromosomal mutation of Chromosomal aberration.

[A] Gene alteration (Gene mutation):

Gene alteration or Gene mutation may be defined as a change in the structure of a gene which is heritable.

- (a) Gene mutation occurs in one or a few nucleotides whithin the DNA molecule.
- (b) Gene mutation generally occurs during the replication of DNA molecule.
- (c) A gene may mutate several times and thus gives rise to multiple alleles.
- (d) A mutant gene may even mutate back to its original form. This type pf mutation is known as reverse mutation or back mutation.
 - (e) Mutant gene does not express immediately because they are generally recessive.
- (f) Gene mutations may occur in nature. This type of mutation is known as spontaneous mutation.
- (g) Mutagenic agents (X-rays, gamma rays, chemicals etc.) can cause the mutation. This type of mutation is known as **induced mutation**.
 - (h) Mutations that occur on the gametes are heritable.

• Types of Gene mutation:

The gene mutations involve a change in base sequences. On the basis of alterations of base sequences, gene mutations may be of the following types—

- (i) **Deletion:** One or more bases are deleted from DNA which represents a gene.
- (ii) Insertion: One or more bases are added in DNA.
- (iii) Inversion: In this case, the sequence of bases are reversed order in DNA.

Changes of genes in the above three types are due to breakage and reunion of DNA segments.

(iv) Replacement or Substitution: In this case, mutaion occurs due to replacement of a base pair during replication of DNA. Here there is no breakage of DNA. Substituions are of two knids, such as transitions and transversions.

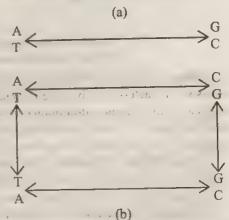


Fig. 7.5: Showing mutations by base replacements.
(a) Transition, (b) Transversion.

(a) Transition: In this case, there is involvement of base pair replacements. Here a purine is replaced by another purine and a pyrimidine is replaced by another pyrimidine i.e. AT (Adenine and Thymine) replace by GC (Guanine and Cytosine) and vice versa. This type of mutation is more common than transversion.

(b) Transversion: Here a purine base is replaced by a pyrimidine base and vice versa. Thus it involves the CG that can be replaced by GC and vice versa. Similarly AT can be replaced by TA and vice versa. In the similar way there is replacement of TA by GC as well as AT by CG in boh directions.

[B] CHROMOSOMAL ABERRATION

Definition: The breaking and reunion of chromatid segments causing distortion in gene sequence is termed as Chromosomal Aberration. They may be Intra-chromosomal or Inter-chromosomal.

[A] Intra-chromosomal: They are mainly of four types, such as deletion, duplication, inversion and iso-chromosome.

[1] Deletion: (Deficiency): Definition: The loss of terminal or intercalary segment

of a chromosome is called deletion.

The deletion in majority of the cases is acentric in nature and the deleted chromosome while pairing with a normal homologous counter part forms a deletion loop (Stansfield, 1986). It is commonly observed in the polytene chromosomes of Drosophila.

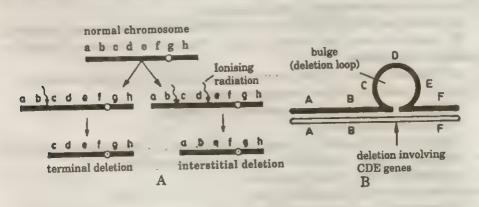


Fig. 7.6: Deletion : (A) Terminal and Interstitial deletion (B) Formation of deletion loop during synapsis (Stansfield '86)

Effects: Change in Phenotypes as in case of notched wing of Drosophila. The recessive characters may become dominant because of the absence of the dominant character, called pseudo-dominance, observed in mice. The deletion in the short arm of chromosome 5, causes the Cri-du-chat syndrome (Lejeune et al, 1963). Similarly delection of the short arm of the human X chromosome causes Turner's syndrome.

[2] Duplication: Definition: The presence of a part of a chromosome in excess of the normal complement is known as Duplication.

The duplication can be of the following types:

[a] Tandem Duplication: The duplicated segment remain adjacent to the normal corresponding section of the chromosome. ABC DEFGH → ABC DEFDEFGH

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[b] Reverse Tandem Duplication: The duplicated sequence is in the reverse order of the normal sequence. ABC DEFGH -> ABC DEF FEDGH

[c] Displaced Duplication: The duplicated segment is not adjacent to the normal segment. It is either on the same side of the centromere (homobranchial) or on the two sides of the centromere (heterobranchial).

ABC DEFGH → ABC DEFGDEF (homobranchial) -> ADEFBC DEFGH (heterobranchial)

[d] Transposed dulpication: The duplicated part of a chromosome gets attached to a non-homologous chromosome, either interstitially or terminally.

[e] Extra-Chromosoma! Duplication: The duplicated segment in presence of a

centromere behave as a complete chromosome.

Effect: Duplication cuases Bar eye in Drosophila, hairy wing in insect, one type of thalassemia in man

[3] Inversion: Definition: The rotation of a part of chromosome segment by 180° on its own axis through breakage and reunion of chromosome segments is known as Inversion.

It is of two types Paracentric (not involving the centromere) and Pericentric (involving the centromere).

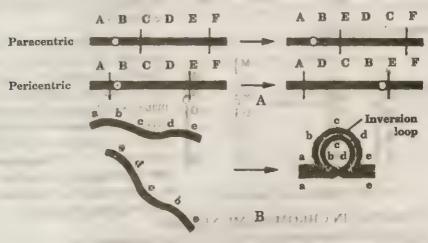


Fig. 7.7: Inversion

(A) Paracentric and Pericentric Inversion, (B) Formation of Inversion loop

The chromosome undergoing an inversion forms an inversion loop while pairing with its normal counterpart.

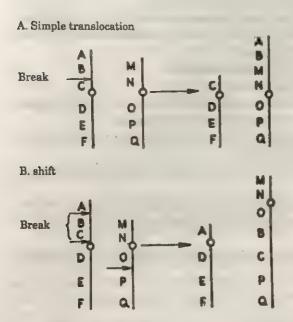
Effect: The inverted chromosome after crossing over can produce di-centric chromosome.

[4] Iso-chromosome: A chromosome breaking at the centromeric region will form two identical chromosomes with similar genetic sequence called iso-chromosome.

[B] Inter-Chromosomal:

[1] Translocation: Definition: The transfer of chromosome segment from one chromosome to a non-homologous chromosome is known as translocation. They are of the following types:

[a] Simple translocation: There is a single break in the chromosome and the



C. Reciprocal translocation

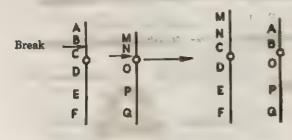


Fig. 7.8: Different types of Translocation

break in the chromosome and the broken piece gets attached to the terminal end of a non-homologous chromosome.

- [b] Shift Translocation: The broken segment of a chromosome gets inserted interstitially in a non-homologous chromosome.
- [c] Reciprocal Translocation: The segment from one chromosome is exchanged with a segment from another nonhomologous one.
- [d] Robertsonian Translocation: When the whole arm of a chromosome fuses with a non homologous chromosome due to eucentric reciprocal translocation, i.e. just outside the centromere.

Effect: Translocation was reported for the first time in Oenothera by de-Vries. Later it was denoted in other plants like maize, wheat, pea etc. The chronic myelocytic leukemia in man is due to loss of longer arm of 22nd autosome (Philadelphia chromosome) and its translocation to chromosome 9. Translocation can also induce lethality.

[C] CHANGE IN CHROMOSOME NUMBER

The change in Chromosome number is known as Polyploidy.

What is Polyploidy?

The condition in which chromosome number increases or decreases by multiples of homologous set or by individual number due to non-disjunction of chromosomes during Anaphase is known as Polyploidy. It is of two types *Euploidy* and *Aneuploidy*.

EUPLOIDY

The condition in which chromosomes are present in exact multiples of the haploid set is termed as Euploidy. It can be artificially induced by application of chemicals like Colchicine or Granosan. Depending on the number of genomes, they can be triploid (3n), tetraploid (4n), pentaploid (5n), hexaploid (6n) etc. Polyploids with odd chromosome number (triploids and pentaploids) are sterile because they have odd chromosome number and does not undergo synapsis, so they propagate vegetatively,

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eg. banana, pineapple. Euploidy is of three types— Autopolyploidy, Allopolyploidy and Autoallopolyploidy.

[A] Autopolyploidy: It is the type of Polyploidy with the numerical increase of the same genome, eg. Autotriploidy (AA), Autotetraploidy (AAAA) as observed in

Maize, Rice etc.

[B] Allopolyploidy: It has developed by hybridisation between two species followed by doubling of chromosomes. The most common being Allotetraploid or Amphidiploid (eg. AABB) as observed in American Cotton, Tobacco.

[C] Autoallopolyploidy: The type of Allopolyploidy where one genome is more than diploid state. They are commonly hexaploids (eg. AAAABB) as observed in *Helianthus* sp.

ANEUPLOIDY

It is the condition in which an organism has fewer or extra chromosomes than the normal diploid number of chromosomes. It occurs due to non-disjunction of homologous chromosomes during formation of gametes. They are of two types: *Hyperploidy* and *Hypoploidy*.

[A] Hyperploidy: [1] Trisomy (2n+1); The condition where one chromosome is in triplicate. eg: Trisomy of 21st Chromosome in Human causing *Down Syndrome*.

Double Trisomy (2n+1+1) has two different chromosomes in triplicate.

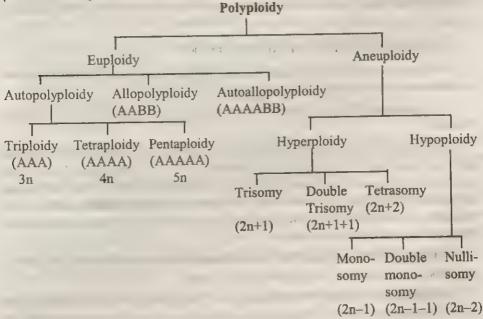
[2] Tetrasomy: (2n+2) The condition where one chromosome is represented four

times as in Apple.

[B] Hypoploidy: [1] Monosomy: (2n-1), The condition in which one chrpomosome is devoid of its homologue. Monosomic condition in human is called *Turner's Syndrome*.

[2] Nullisomy: (2n-2). The condition in which an organism is deficient in a complete

pair of homologous chromosomes causing lethality.



• EXAMPLES OF TRISOMY IN MAN

[A] Autosomal Trisomy

- [1] Down Syndrome Trisomy of 21st Chromosome
- [2] Edward's Syndrome Trisomy of 18th Chromosome.
- [3] Patau's Syndrome Trisomy of 13th Chromosome

[B] Sex Chromosomal Trisomy

- [1] Klinefelters' Syndrome Extra X chromosome is present (XXY)
- [2] Turner's Syndrome Only one X chromosome present (XO)
- [3] Criminal like Behaviour Extra Y chromosome present in male (XYY)

• Inportance of mutation:

Mutations are of great importance for the welfare of human society They are of great use to plant breeders and animal breeders. Some of which are given below.

- 1. New and useful varieties of rice, wheat and other economically important plants are produced by mutation. Delicious apples, oranges and seedless grapes are all the result of mutational changes.
 - 2. Mutations increased the production of penicillin from mold Penicillium.
- 3. Mutations cause variability in organisms, as a result they can adapt in the new environment.
 - 4. Mutations are important for the improvement domesticated animals.
- 5. Mutation alone cannot account for evolution, rather mutation furnishes the raw material on which other forces act to bring about the evolutionary changes in the living organisms.

7.8. Gene

Definition: Gene is a functional fragment of DNA nucleotide capable of synthesizing a specific protein and acting as the unit of inheritance.

7.8.1. DEVELOPMENT OF GENE CONCEPT

The structure and function of gene was denoted by several scientists and the gradual development of the concept is illustrated below:

- [1] **Johannsen** (1903) introduced the term *Gene* in place of the *Factors* denoted by Mendel.
- [2] Garrod (1909) studied in details the 'Inborn Errors of Metabolism' in human and concluded that diseases like phenylketonuria (PKU) or alkaptonuria are due to absence of enzymes phenyl alanine hydroxylase and homogentisic acid oxidase causing accumulation of phenyl pyruvic acid in blood and homogentisic acid in urine respectively. This observaion suggested that the inactivation of certain genes caused the deficiency of these enzymes.
- [3] **Belling** (1928) suggested that the **chromomeres** arranged linearly as a series of granules on the chromatid are representing the genes.
- [4] Beadle and Tatum (1941) denoted the 'One gene one enzyme' theory in the fungus Neurospora crassa. The synthesis of arginine is a multistep process and the

wild strain in which all the enzymes were present was called prototrophs and it grew safely in the minimal medium. But the mutants developing from the prototrophs which could not grow in minimal medium was called auxotroph. This was because they lacked some specific enzyme required for the biosynthesis of arginine. The absence of such enzymes was due to inactivation of specific genes by mutation, which clearly indicate the 'one gene one enzyme' hypothesis.

- [5] V. Ingram (1957) indicated the expansion of the previous theory and proposed the 'One gene-one polypeptide theory' He observed that in human the normal haemoglobin (HbA) contained the 2α and 2β protein chains in the globin portion, but in Sickle-cell anaemia (Hbs), the 6th amino acid, glutamic acid in the β chain is replaced by valine causing the formation of Sickle shaped RBC. Thus one gene controls the activity of one polypeptide directly.
- [6] Calan and Lloyd (1960) denoted in the lampbrush chromosomes that each loop was formed of two types of genes, the Master gene and Slave gene. The activity of the latter is controlled by the former genes.
- [7] **F. Jacob and J. Monod**. (1961) while studying catabolism of lactose in *Escherichia coli* denoted a unique model of gene regulation called the **Operon model**. It is also called **Lac-Operon**. The genes are as follows:
- [a] Regulator Gene: (I) It is also called inhibitor gene, it codes for a repressor protein which has two binding sites, one binding with the operator gene while the other binding with the inducer (lactose).
- [b] Promoter gene (P): It is the point where the RNA polymerase is associated and operator gene is controlled.
- [c] Operator Gene: (O): This gene interacts with the repressor protein and prevents the activity of the structural genes.
 - [d] Structural genes: In a lactose operon there are three structural genes:

Lac X coding for enzyme transacetylase.

Lac Y coding for enzyme permease.

Lac Z coding for enzyme β - galactosidase.

Operation of Lac Operon :

The repressor protein produced by regulator gene binds with operator gene, the structural genes cannot work and the process is switched off. The adding of lactose binds with the repressor and the process is switched on.

The **Tryptophan Operon** is another operon with five structural genes and it explains **feed back repression**. The repressor protein released by the regulator gene cannot bind with the operator and it is called **apo-repressor**, which keeps the process switched on. But Tryptophan, when added binds with apo-repressor and called **co-repressor**, swiches off the process.

Shapiro et al (1969) first purified lac-operon and observed it under electron microscope.

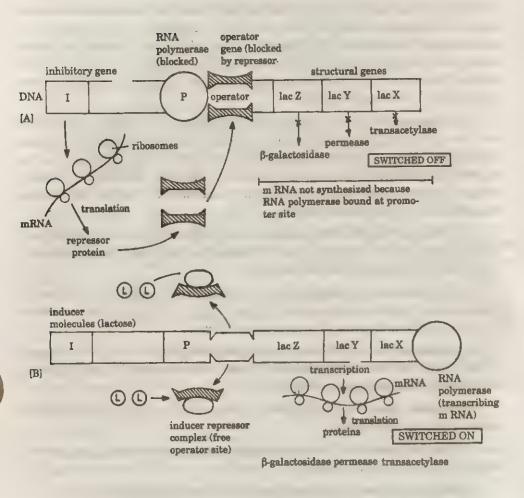


Fig. 7.9: Lac operon model of gene regulation in bacteria
(a) Operon in switched off position with repressor bound to operator

- (b) Operon in switched on position with repressor inducer complex that removes repressor to free operator site.
- [8] Glover and Hogness (1977): They denoted that the structural genes can control the activity of many polypeptides, so the one gene one polypeptide was replaced by One gene many plypeptide theory.

7.8.2. TYPES OF GENES

- [1] Holandric gene: The genes present in the Y chromosome, helping in paternal transmission of characters.
- [2] Jumping Gene: The DNA sequences which can change positions within one chromosome or between chromosomes is known as transposons or jumping genes.
 - [3] Lethal Gene: The genes causing lethality in an organism.
 - [4] Onco Gene: The genes inducing neoplastic growth in an organism.
- [5] Overlapping Gene: The genes which are functional within large sized genes as in case of some viral gene.

[6] Plasma Gene: The extranuclear inheritance brought upon by the DNA present in the cytoplasmic organelles.

[7] Pseudo-Gene: The part of the DNA not involved in transcription is known as

Pseudo-Gene.

- [8] **Split Gene**: The entire DNA can be divided into functional sequences called exon and non-functional repetitive sequences called introns. This dual nature of the DNA has been termed as Split gene.
 - Division of labour within genes: Benzer (1955) identified five different types of genes on the basis of their functions. They are as follows:
 - [a] Muton: The smallest sequence of DNA capable of undergiong mutation, which should at least have a pair of Nitrogen bases.
 - [b] Recon: The smallest DNA segment which induces crossing over.
 - [c] Cistron: The functional DNA segment coding for a single polypeptide.
 - [d] Complon: The particular DNA segment coding for more than one polypeptide.
 - [e] Replicon: The DNA segment consisting of more than one complon.

7.9. Genetic code

The DNA contains the nitrogen bases, three nitrogen bases together (triplet) code for one of the twenty essential amino acids. Thus $4^3 = 64$ possible combinations of codons are available for coding 20 amino acids. These discoveries were made by Nirenberg, Matthaei and Khorana in 1961. Khorana and Nirenberg got the Nobel prize for this discovery in 1968.

7.9.1 PROPERTIES OF GENETIC CODE

- [1] Codon is triplet: Three nucleotides code for one amino acid.
- [2] Codon is degenerate: More than one codon code for an ammo acid [Degenerate codon, first 2 bases are fixed, 3rd one changes, which is called Wobble's Hypothesis.]

[3] Codon is Commaless: There is no gap in between codons.

[4] Codon is Non-ambiguous: Each codon is specific for an amino acid, (can be Ambiguous sometimes, UUU codes for phenylalanine, it codes for leucin in presence of Streptomycin.)

[5] Codon is Universal: It is same in all organisms from virus to man.

- [6] Terminating codon: The 3 Codons, UAA, UGA and UAG cannot code for any amino acid, they terminate the translation process and are also called Nonsense Codons.
- [7] Initiating Codon: The codon AUG coding for Methionine starts the protein synthesis and are called initiating codon.

7.10. Protein synthesis:

The term protein synthesis means polypeptide synthesis which mainly include two major phases.

- [A] Transcription: Synthesis of m-RNA on the DNA.
- [B] Translation: Synthesis of polypeptides as per the codon of m-RNA.

Central Dogma: Synthesis of m-RNA from DNA by transcription and synthesis of polypeptide from m-RNA is termed by translation is known as Central Dogma. Synthesis of DNA from RNA is found in cancer viruses and it is called reverse transcription.

[A] Transcription: Definition: The transfer of genetic information from DNA to m-RNA is known as transcription. Then RNA formed is not binding with the DNA with hydrogen bonds, so it separates easily and goes to the cytoplasm. There are four major steps of Transcription.

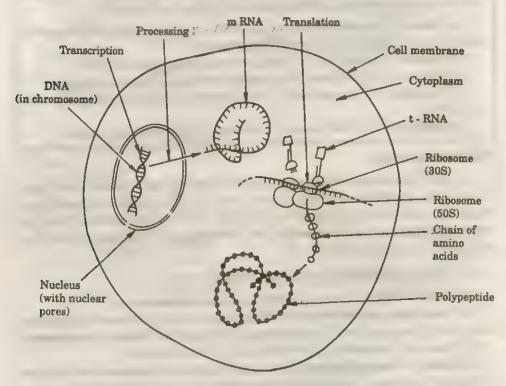


Fig. 7.10: Diagrammatic Representation of Protein Synthesis

- [1] Initiation of m-RNA synthesis: The m-RNA synthesis starts on the DNA at a particular region rich in A=T having th sequence TATA ATG, commonly called TATA box. The sigma factor (σ) is helping as the recognition signal.
- [2] Elongation of m-RNA polynucleotide: The elongation of m-RNA takes place from 5 to 3 direction. The first nucleotide incorporated is always A or G. The elongation occurs at a speed of 30 nucleotides per second.
- [3] **Termination of m-RNA synthesis:** The termination of m-RNA synthesis occurs after recognition of the termination signal and it is helped by the rho factor. The termination occurs in a GC rich region in prokaryotes and AT rich region in eukaryotes.
- [4] Processing of m-RNA polynucleotide: The m-RNA polynucleotide is shortened by splicing off of the repetitive sequence. These is an attachment of a tail composed of

multiple adenine and this is called polyadenylation which is helping in the transfer of m-RNA into the cytoplasm.

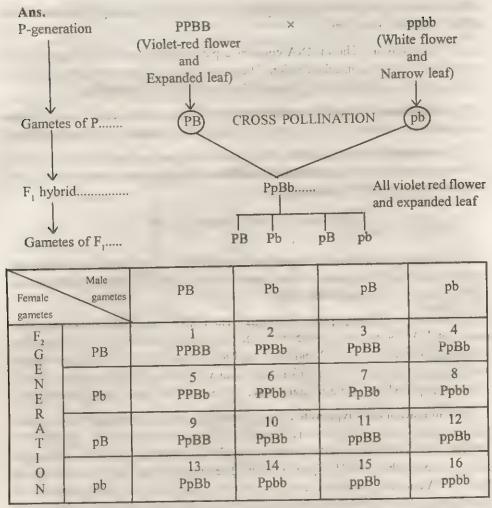
- [B] Translation: The m-RNA contains a particular sequence of nitrogen bases remaining in triplet form, called codon. The codons bind with the anticodon of t-RNA and the amino acid is drawn in. There are six major steps of translation:
- [1] Attachment of m-RNA to 30 ribosome: The m-RNA after coming to the cytoplasm binds with the 30 S sub-unit of the ribosome in presence of F₂ protein factor.
- [2] Activation of Amino acids: The Amino acids are activated with the help of ATP in presence of specific Amino acyl synthase enzyme to form Aminoacyl adenylate enzyme complex and Pyrophosphate.

$$AA_1 + ATP \xrightarrow{Amino Acyl} AA_1 - AMP - enzyme + PP_1$$
.

- [3] Transfer of activated Amino acids to t-RNA: The Amino-acyl adenylate enzyme complex gets attached to the specific t-RNA with the help of hydrolysis of AMP at the CCA terminal of the t-RNA.
- [4] Initiation of polypeptide Synthesis: The t-RNA containing Methionine with anticodon UAC is attracted towards the m-RNA initiating codon AUG. It is helped by initiating proteins (IF-1, IF-2 and IF-3) and hydrolysis of GTP. The larger subunit (80S for eukaryote and 70S for prokaryote) binds with 30S m-RNA complex. It has 2 sites, the peptidyl site and aminoacyl site. The met-t-RNA binds at the peptidyl site.
- [5] Elongation of Polypeptide: The second codon at the amino-acyl site atttracts the 2nd amino acyl t-RNA. This is helped by 2-elongation factors (EF Ts and EF Tu) and GTP. The COOH of the first amino acid binds with the NH₂ of the 2nd amino acid by forming the CO-NH or peptide bond. The ribosome then moves to the right on the m-RNA and the 2nd amino acid shifts from the amino acyl site to the peptidyl site by dislodging the met-t-RNA at the peptidyl site. As the ribosome moves along the 5' to 3' direction on the m-RNA strand, about 8-15 amino acids are incroporated into the growing polypeptide chain.
- [6] Termination of Polypeptide synthesis: There are three terminating codons UAA. UAG and UGA which are recognized by any of the 2 releasing factors RF₁ or RF₂. The recognition of the terminating codons at amino-acyl site blocks the polypeptide synthesis process, the ribosomes are dissociated, the polypeptide chain is set free in the cytoplasm.

7.11. Problems in relation to genetics

[1] In snap dragon violet-red flower (P) is completely dominant over white flower (p). Again the expanded leaf (B) of the plant is dominant over narrow leaf (b). If a violet-red flower and expanded leaf snap dragon is crossed with a white flower and narrow leaf snap dragon. What type of plants will be produced in F_i ? Show the heterozygous plants for both the characters in F_2 by a checker board. (J.E.E. 1979)



1. Type of plants in F1: All plants are Violet-red flower and expanded leaf

2. Heterozygous plants for both the Characters in F,:

In checker board numbers 4, 7, 10 and 13 and their genotypes 4 = PpBb, 7 = PpBb, 10=PpBb and 13 = PpBb.

[2] A blue-eyed man both of whose parents were brown-eyed marries a brown-eyed woman. They have one child, who is blue-eyed. What are the genotypes of all individuals mentioned? Mention which are phenotype in the above statement.

[J.E.E. 1993]

Ans. As the parents of blue-eyed person are brown-eyed, so the parents are heterozygous; hence brown-eyed (B) is dominant and blue-eyed (b) is recessive. When blue-eyed man marries a brown-eyed woman, the son becomes blue-eyed then the women is definitely heterozygous; the son and father are homozygous.

Hence the genotypes of the individuals are as follows-

- (i) Brown-eyed parents (Heterozygous)—Bb
- (ii) Blue-eyed men (Homozygous)-bb
- (iii) Brown-eyed woman (Heterozygous)—Bb

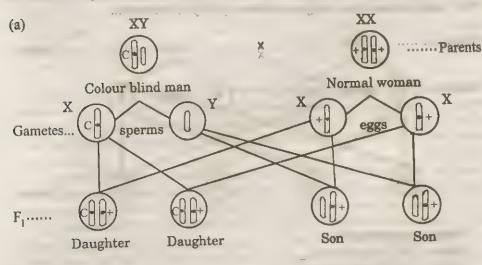
(iv) Blue-eyed son (Homozygous)-bb It is supported by the the following cross chart-Brown-eyed......Parents Brown-eyed Bb Bb Bb Blue-eyed man Brown-eyed Brown-eyed woman Blue-eyed man Again bB testriques (I bb Blue Brown Blue Brown Offsprings... eyed eyed eyed

From the above cross the phenotypes are of two kinds, such as Brown-eyed and blue-eyed.

[3] In man, gene for colour blindness is sex-linked. What type of children will be born in F_1 if (a) a colour blind man marries a normal woman and in F_2 if (b) F_1 daughter marries a colour blind man? [J.E.E. 1990]

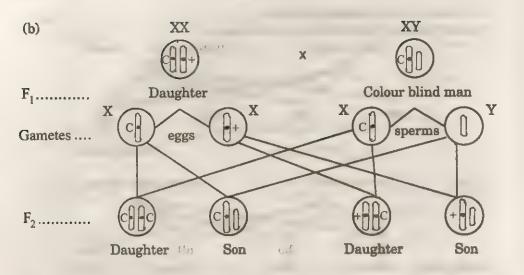
Ans. Colour blindness means inability to differenciate between red and green colour. Colour blindness is genetically regulated by recessive gene, 'c' located on the 'X' chromosome. In normal woman, both the normal genes are located on two chromosomes. But in colour blind man, the gene for colour blind is located on the 'X' chromosome and there is no allele in the 'Y' chromosome.

Here 'c' represents gene for colour blindness.



Daughters: Normal but carriers of colour blind gene.

Sons: All normal.



Daughters : 25% colour blind

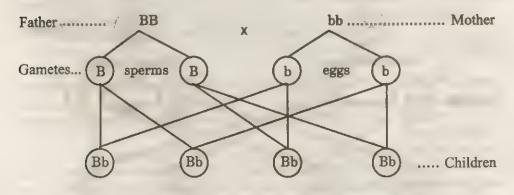
-25% Normal but carrier of colour blind gene.

25% colour blind. Son: —25% Normal.

[4] In man brown eye (B) is dominant over blue eye (h). A brow-eyed man marries a blue-eyed woman and they have six children who have all brown eyes. What are the genotype of all the members of the family? Give reasons for your answer.

[J.E.E. 1989]

Ans. Mother is a blue-eyed and all the children are brown-eyed. So the mother possess double recessive genes as 'bb' and the brown-eyed childrens receive one gene 'b' from their mother and definitely they have received one gene 'B' from their father. Hence the genotype of all childrens will be 'Bb' and the father's genotype will be 'Bb'. Now the cross chart has given below to justify the statement.



Hence the genotypes of:

Father—BB (Homozygous)

Mother-bb (Homozygous)

All the children—Bb (Heterozygous)

[5] Tall tomato plants are produced by a dominant allele D and dwarf plants by its allele d. Hairy stems are produced by a dominant allele H and hairlss stems by its recessive allele h.A. dihybrid tall hairy plant is test crossed. In the F_1 progeny there were 118 tall hairy, 121 dwarf hairless, 112 tall hairless and 109 dwarf hairy plants.

(i) Represent the cross.

(ii) Find out the ratio of tall: dwarf and harry: hairless.

[J.E.E. 1986]

Ans. [i] Test cros is represented here: The genotype of tall hairy tomato plant is 'DdHh' which is heterozygous. Now it is crossed with the double ressive homozygous 'ddhh' tomato plant.

Dihybrid tall hairy plant Ddhh	× Homozygous recessive ddhh
Gametes DH Dh dH dh	dh : eve (brown eye

	DH	Dh	dН	dh
	DdHh	Ddhh	ddHh y y y	ddhh
h	Tall hairy	Tall hairless	Dwarf hairy	Dwarf hairless
	118	112	109	121

Hence F, progeny:

dł

Genotype	Phenotype	No.obtained	Ratio (approx)
1. DdHh 2. Ddhh 3. ddHh 4. ddhh	25 17 000 3	20 gnf 112 112 hpc dd 109	4
[ii] Ratio :—Tall 118 + 112 = 230 or		and hairy & 118+109=227 & 1	: hairless : 112+121 = 223 : 1

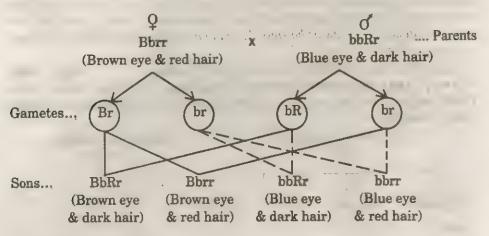
[6] In man, brown eyes (B) are dominant over blue eyes (b) and dark hairs (R) dominant over red hairs(r). A man with brown eyes and red hairs marries a woman with blue eyes and dark hairs. They have two children, one with brown eyes and red hairs and the other with blue eyes and dark hairs. Give the genotypes of the parents and children.

[J.E.E. 1985]

Ans. As the brown eyes and dark hairs are dominant so there will be two types of genotypes in the parents, such as (1) BBrr and bbRR or (2) Bbrr and bbRr. Two types of crosses are shown here between the two types of genotypes of the parents.

1. Gametes of BBrr and bbRR of the 1st type of parenets will be Br and bR respecttively. After fertilization the genotype will be BbRr and so one type of son with brown eyes and red hair will be developed. As a result, such genotypes of the parents do not satisfy the condition.

2. Cross is made between the second type of genotype of the parents.



Hence the genotypes:

Parents-Bbrr and bbRr

1st. son-Bbrr (Brown eye and red hair)

2nd son-bbRr (Blue eye and dark hair)

[7] Aa and Bb are two different alleles with A dominant over a and B dominant over b. Sketch the anaphase of first and second meiotic division and also the resulting gametes in the following three cases to show genic composition assuming that alleles Aa and Bb are carried—

(i) In different pairs of homologous chromosomes $\begin{bmatrix} A & B \\ \hline a & and \\ \hline b \end{bmatrix}$:

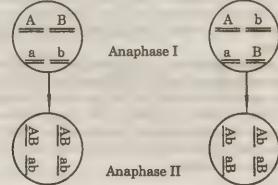
(ii) In the same pair of homologous chromosomes $\left[\begin{array}{c} AB \\ \hline ab \end{array}\right]$ with a crossing over in between Aa and Bb; and

(iii) In the same pair of homologous chromosomes AB but without crossing over in between Aa and Bb loci

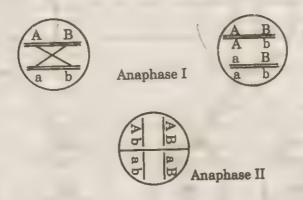
(Only sketch drawings are required)

From your sketch, determine the cases which follow Mendel's law of independent assortment. Give reasons. [J.E.E. 1983]

Ans. Sketch diagrams of chromosomes during anaphase stage of meiosis with reasons are given below.



Aa and Bb alleles are situated in two different pairs of homologous chromosomes. So in meiosis I, AB and ab both move separately in opposite pole. Or Ab and aB both move separetely in opposite direction in anaphase stage. In meiosis II, in each daughter cell the chromatids of each chromosome are separated and move in opposite pole and so gametes will be AB, ab/Ab, aB. This is following the law of independent assortment.



If there is crossing over between the alleles (Aa & Bb) in the homologous chromosomes, then in anaphase stage of meiosis I chromosomes containing Ab and aB move separately in opposite pole. As a result, in two daughter cells Ab andd aB two chromosomes are present. In anaphase of meiosis II, ab chromatids move in opposite pole in Ab cell. Here law of independent assortment is observed in two alleles. Gametes are Ab. aB.

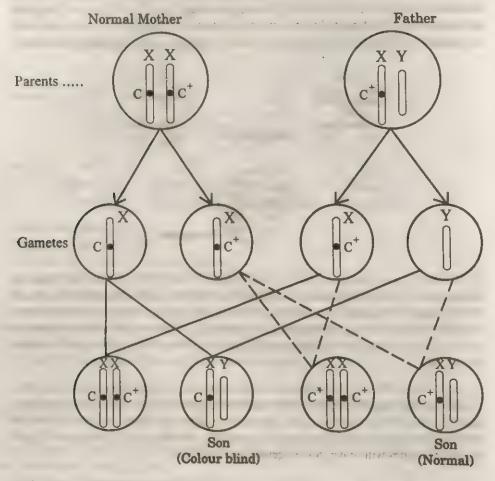
(iii) Aa and Bb alleles are present in the same pair of homologous chromosomes. As there will be no crossing over, so in anaphase of meiosis I AB will move in one pole and ab will move in opposite pole. In each daughter cell there will be AB and ab chromosomes respectively. As a result, in anaphase of meiosis II, in each pole AB and ab chromosomes will move. So the gemetes are AB, ab.



[8] A common kind of red-green colour blindness in human is caused by the presence of a sex-linked reessive gene C whose normal allele is C⁺. A normal woman whose mother was colour blind has a son. Nothing is known of the colour-vision phenotype of th father. What is the probability that the son will be colour blind? [J.E.E. 1984]

Ans. The normal woman is the carrier of the colour blindness gene beause her mother was a colour blind. Son of the carrier woman is colour blind but his father's colour-vision phenotype is unknown. The son does not inherit th 'X' chromosome of

the father but inherit 'Y' chromosome. Colour blindness gene does not present in the Y chromosome. Now the cross chart has given below to justify the statement.



So in the cross it has been observed that out of the two sons one is normal and the other son is colour blind. Hence there is 50% chance of colour blindness among the sons.

7.12. MATTERS TO RECOLLECT

- Mendel's laws of inheritance first published in 1866 in an annual proceedings of the 'Natural History Society' at Brunn, Austria (now in Czechoslovakia).
- In 1900 three biologists, *Hugo de Vries* of Holland, *Eric Von Tschermak* of Austria and *Karl Correns* of Germany rediscovered Mendel's work.
- Mendel selected his experimental material as garden pea (Pisum sativum) mainly due to its peculiarity of flower structure, availability of many pure varieties of pea plant and fertility of hybrid plants.
- Out of many varieties of pea plant, Mendel selected only seven varieties of contrasting characters.
- Mendel made hybridization experiments with these seven pairs of contrasting

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characters both in monohybrid as well as dihybrid crosses upto F, and F, generations.

- Mendel deduced two laws, Law of segregation and Law of independent assortment from his monohybrid and dihybrid crosses on garden pea.
- After rediscovery of Mendel's principles of heredity, many geneticists worked on varieties of plants and animal materials. They observed that the law of segregation is applicable in all cases but the law of independent assortment is applicable only when two pairs of alleles are present in two separate pairs of homologous chromosomes. Genes that are located in the same chromosome pair do not behave independently due to linkage.
- The principle of dominance is not applieble in all cases but in some cases *incomplete* dominance also occurs.
- Mendel considered that the expression of single phenotypic character of an organism depends on the interaction of two alleles of a factor which is now known as *gene*.
- Now it has been observed that more than one gene interact in the expression of a particular character. The expression of a gene may be suppressed, enhanced or altered by other genes.
- A gene in the same locus may mutate many times and form the *multiple alleles*.

 ABO blood group is an example of multiple alleles of human population.
- Multiple gene or polygenic inheritance also occurs in human skin colour. Here two or more pairs of genes are acting on a trait. On the other hand, a single gene may influence in the expression of two or more traits.
- Genes are arranged in a linear fashion in a chromosome and they are linked one another to form a *linkage group*. But *crossing over* causes the new combinations of genes in an homologous pair, as a result new phenotypic characters are expressed. Location of genes in a chromosome can be traced out by *chromosome mapping*.
- In the sex linked inheritance such as haemophilia, color blindness etc. males are more sufferer than females. Females are the carrier of the disease.
- Mutations may occur in the gene or by rearrangement of genes or by chromosomal aberrations or by increase of the number of chromosomes.
- Gene is a functional fragment of DNA nucleotide capable of synthesizing a specific protein.

7.13. Summary

Heredity is the transmission of characters from one generation to the subsequent generations. Principles of heredity first indroduced by Geogor Johann Mendel, an Austrian Monk in the year of 1866. But these principles were unknown for many years. In 1900 Hugo de Vries, Eric Von Tschermak and Karl Correns these scientists rediscovered the Mendel's work. Mendel actually laid the foundation of the modern science of genetics and so he is now regarded as the 'father of genetics'.

Mendel selected the garden pea plant (*Pisum sativum*) as an experimental material and continued his hybridization experiments for long eight years. He recorded all these experiments and also its results. He deducted certain principles from these statistical records.

Mendel selected seven traits with their alternative forms of garden pea plant. In all the hybridization experiments, Mendel observed that all the offsprings of F₁

generation exhibited only one parental form but both the forms of the parental generation were exposed in F_2 generation. So he concluded that the expressed form in F_1 is the dominant and the other unexpressed form is the recessive. By test cross he proved that the characters were not blended rather both the forms exposed in F_2 generation in the ratio of 3:1—i.e. 75% dominant form and 25% recessive form. This ratio is regarded as the 'Mendelian Monohybrid ratio'. Mendel deduced a law from the monohybrid cross that is known as law of segregation.

Dihybrid cross (two pairs of alleles controlled by two genes) exhibited the dominant characters of both genes in F_1 generation but in the F_2 generation two parental and two recombinants are expressed and the ratio was 9:3:3:1. Mendel concluded from this ratio that each pair of alleles distributed independently to the progeny. This is known as law of independent assortment.

Subsequently geneticists hybridized many plants and animals. They observe that complete dominance is not universal rather incomple dominance (one allele is not fully dominant over the other allele) is also present in many cases. The law of independent assortment is not universally applicable due to linkage phenomenon.

Mendel thought that one trait with its alternative forms controlled by one factor (now known as gene) with a pair of alleles. But it has now been shown that in many cases more than one gene (more than one pair of alleles) influence each trait. As a result, many modified dihybrid ratios are obtained instead of Mendelian dihybrid ratio 9:3:3:1.

In 1910, Morgan discovered linkage phenomenon in *Drosophila*. Linkage may be of two types, such as complete and incomplete linkage. Complete linkage occurs in male *Drosophila*. Crossing over takes place in incomplete linkage, due to this recombination of genes takes place. Percentage of crossing over helps in the chromosome mapping.

Colour blindness and haemophilia are the two very important sex-linked recessive traits in man. In the sex-linked inheritance males are more suffer and the females are carrier. Traits are handed over to the offsprings in a criss cross fashion.

Mutation occurs in the gene or in the change of chromosome or increase in the number of chromosomes. Mutations may occur in nature or artificially by irradiation. Mutations that occur in gametes are heritable.

Gene is a functional fragment of DNA. The DNA contains the nitrogen bases. The three nitrogen bases are together code for one of the twenty essential amino acids. The protein is synthesized by two processes, namely Transcription and Translation.

7.14. Naming/Discovery/Discoverer

- 1. Aristole (350 B.C.) Introduced the theory of heredity known as 'fluid theory'.
- 2. Anton von Leeuwenhoek (1677): He was an idea of 'preformation theory'.
- 3. Charles Darwin (1866): Proposed the 'pangenesis theory'.
- 4. Gregor Johann Mendel (1866): Introduced the 'laws of heredity'.
- 5. Hugo de Vries, Eric von Tschermak and Karl Correns (1900): 'Rediscovered' the mendel's laws of inheritance.
- 6. W. Bateson (1905): The term 'genetics' was first introduced.
- 7. W. Johannsen (1909): The term 'gene' was first introduced by him.

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8. W. Bateson and R.C. Punnett (1906): They observed in sweet pea some deviations from Mendel's law of independent assortment and formulated the 'coupling and repulsion theory'.

 Thomas Hunt Morgan (1910): Showed in *Drosophila* (fruit fly) that coupling and repulsion are the two aspects of a single phenomenon which he called linkage.

He discovered the sex-linked inheritance in Drosiophila.

10. Curt Stern (1931): The cytological evidence of crossing over was given by him.

11. J.B.S. Haldane: Termed the unit of crossing-over as 'morgan'. If 2.5% crossing-over occurs between two genes, the genes under consideration are said to be

2.5 morgans apart.

12. A.H. Sturtevent (1913): Developed the idea that the percentage of crossingover could be used to determine the relative positions of genes in chromosomes. With this concept he developed with the first *chromosome map*, showing the position of genes.

13. Wilson and Stevens (1905): Showed the importance of 'X' chromosome in

sex determination.

- 14. J.D. Watson and F.H. Crick (1953): They proposed a model of the structure of DNA molecule (double helix). This is known as *Watson-Crick model* of DNA molecule.
- 15. George Beadle and Edward Tatum (1941): They introduced one gene-one enzyme theory. Each enzyme is controlled by a specific gene.
- 16. Har Gobind Khorana (1970): Synthesized m-RNA and establish a codon dictionary.
- 17. F. Jacob and J. Monod (1960): They proposed the operon hypothesis to explain how protein synthesis may be repressed or induced.
- 18. H.J. Muller (1927): He was the frist to demonstrate that radiations cause mutations. He also evolved a method to detect all recessive mutant genes.
- 19. **Correns** (1908): He was the first to describe a non-chromosomal gene. It has been observed that in certain cases, a small percentage of inheritance takes place through the cytoplasm *i.e.* cytoplasmic inheritance.

7.15. Answers to Special Questions

[1] What are heredity and geneties?

Ans. Heredity deals with the transmission of genes, and hence characters, from parents to offsprings. Genetics covers heredity as well as its variations.

[2] What is a gene? [J.E.E. 1986]

Ans. Gene is the functional unit of hereditary material, DNA that determines the biological character of an organism ans responsible for the appearance and inheritance of a character.

[3] What is the difference between recessive and dominant genes?

[J.E.E. 1986, '88]

Ans. (i) A hetrozygote possesses two contrasting genes, but only one of the two is able to express itself, while the other remains suppressed.

(ii) The gene which gains phenotypic expression in a hybrid is known as

dominant gene.

(iii) The other gene which is unable to express itself in presence of the dominant gene is known as recessive gene.

[4] What is allele or allelomorph?

[J.E.E. 1986]

Ans. A pair of genes that represents contrasting alternatives of a character and located at the same locus in the homologous chromosomes is known as allele or allelomorph.

[5] What is crossing over? State the importance of crossing over/What is the importance of crossing over? [J.E.E. 1986, '91]

Ans. Crossing over is a phenomenon of break and rejoin of segments between the non-sister chromatids of a bivalent during diplotin of prophase where by exchange of genetical materials between the two.

Improtance: (i) Crossing over helps in the great genetic diversity by reorganization of the genetic complement and there by helping indirectly in his increased evolutionary potential in the organism.

(ii) Crossing over makes possible mapping of genes on chromosome.

[6] What is a test cross?

[J.E.E. 1986]

Ans. Test cross is a cross between heterozygous F_1 hybrid and the double recessive homozygous parent. This is used to determine whether the individuals exhibiting dominant character are homozygous or heterozygous.

[7] What is phenotype?

[J.E.E. 1993]

Ans. The external appearance or characteristics manifested by an individual is known as phenotype.

[8] Distinguish between a phenotype and a genotype. / What do you mean by Phenotype and Genotype?

[J.E.E. 1991]

Ans.

Phenotype	Genotype
1. The external appearance or characteristics are manifested by an individual.	1. Genotype is the genetic constitution of an individual.
2. Characters are visible to the naked eyes in case of macroorganism but microscopic examination are necessary for microorganism.	

[9] What is Mendel's principle of 'independent assortment'? [J.E.E. 1991]

Ans. When two pairs of independent alleles enter into combination in the F₁, they exibit independent dominant effects. On the formation of the gametes the law of segregation operates but the factors assort themselves independently at random and freely.

[10] Define homozygous and heterozygous. [J.E.E. 1988]

Ans. (i) Homozygous: When both the genes in a particular locus of a homologous pairing are of the same nature of character (dominant or reessive) then that individual on the basis of that character is said to be homozygous (pure form).

- (ii) Heterozygous: When in a particular locus of a homologous pairing if there is allele then that individual on the basis of that character is said to be heterozygous (hybrid form).
- [11] What kind of factor interaction is indicated when the phenotypic ratio 9:3:3:1 of the F₂ generation is modified to 3:6:3:1:2:1? [J.E.E. 1991] Ans. When in a dihybrid cross, one character shows complete dominance classes and the other shows incomplete dominance, the F₂ ratio is modified and 6 classes in the ratio of 3:6:3:1:2:1 are observed instead of 4 classes.
- [12] Give examples of modern findings which appear to contradict or cannot be fully explained by Mendel's Laws of Heredity. [J.E.E. 1987]

Ans. Examples of modern findings are given below-

- (A) Law of dominance: Modifications are due to—single gene have manifold effects (interaction of genes).
- (a) Lethal gene or Lethal factor ratio (2:1)—Monohybrid ratio deviation.
- (b) Dihybrid ratio deviations: (i) Complementary factors (9:7), (n) Inhibitary factors (13:3), (iii) Supplementary factor (9:3:4), (iv) Epistasis (12:3:1),
- (v) Duplicate factors (15:1), (vi) Multiple factors.
- (B) Law of independent assortment: Limitations are better explained by law of linkage.
- [13] What is linkage?

Ans. Linkage is now defined as the tendency of genes on the same chromosome to remain together during the process of inheritance.

[14] What are sex-linked genes?

[J.E.E. 1985]

Ans. Gencs which are located in the sex chromosomes but are not related with sex are known as sex-linked genes. Examples—For Haemophilia and Colour blindness sex-linked recessive genes are present in the sex chromosomes.

[15] What is cris-cross pattern of inheritance?

Ans. This type of inheritance of the recessive sex-linked character from P_1 generation to F_2 male generation through F_1 female is called criss-cross pattern of inheritance. Here sex-linked recessive character remains unexpressed in the F_1 generation.

[16] What is sex-limited genes?

Ans. Sex-limited genes may be located in any of the chromosomes in both sexes but express themselves only in one sex. Their expression is governed by the presence or absence of one of the sex-hormones. The sex-limited genes control the expression of secondary sexual characters.

[17] What is sex-influenced genes?

Ans. Sex-influenced genes may be located in any of the chromosomes. But they are expressed more frequently in one sex particularly in man. The expression of these genes is influenced by sex-hormones. Baldnessof man is an example of sex-influenced trait.

[18] What is cistron?

Ans. Cistron is the functional unit of DNA molecule and the cistron can also be called a genetic unit of DNA molecule.

[19] What is lethal gene?

Ans. A lethal gene is that which produces an effect so sharply different from the

normal one that its possessor is unable to survive. Most lethal genes are recessive and cause death only when homozygous.

[20] What is epistasis?

Ans. When two independent genes affect the same character of an organism and expression of one gene hides the effect of another gene then this phenomenon is known as epistasis.

[21] What is complementary genes?

Ans. In this case, each pair of alleles is located in separated pair of chromosomes. When both the alleles are essential for the expression of a particular character such genes are known as complementary genes.

[22] What is supplementary genes?

Ans. When two independent but dominant genes are interacting in such a way that a different type of phenotype expression is developed; such genes are known as supplementary genes.

[23] Name one common hereditary disorder which is carried on by autosomes. [J.E.E. 1989]

Ans. Autosomal disorder in man is observed in Down's syndrome or Mongoloid idiocy.

[24] What is Turner's syndrome?

[J.E.E. 1989]

Ans. In human's, mechanical error in the separation of homologues during meiosis, can produce exceptional XO individuals that have an 'X' but no Y chromosome; these are found to be sterile females.

[25] What is multiple allele? Give one example.

Ans. When two or more alleles control one character then these genes are collectively called multiple alleles.

Example: ABO blood group is controlled by more than one alleles.

[26] What is Barr body?

[J.E.E. 1989]

Ans. One of the 'X' chromosomes is heterochromatic and its stainability is different from the other 'X' chromosome and autosomes. This heterochromatic 'X' chromosome is known as Barr body. Barr body is present in the normal female but not in the normal male.

[27] What are the chromosomal make-up of the following conditions: (i) Turner's syndrome (ii) Klinefelter's syndrome (iii) Down's syndrome.

[J.E.E. 1989]

Ans. (1) Turner syndrome: There are only 45 chromosomes and only one sex chromosome, an 'X'. The sex-chromosome constitution is said to be XO (44A+XO).

(ii) Klinefelter's syndrome: There are 47 chromosomes, there being two 'X' chromosomes and a 'Y'. The sex-chromosome constitution is said to be XXY i.e. (44A+XXY)

(iii) Down's syndrome: It is an autosomal abnormality in man. The chromosomal constitution in most cases is trisomy of chromosome 21 (three chromosomes 21 rather than two) i.e. 45A+XX/XY.

[28] What are the clinical features in Down's syndrome or Mongoloid idiocy? Ans. The clinical features are:

(i) Mental retardation (n) Folds of the eyelids of Mongoloid peoples (iii) Short stature (iv) Stubby hands and feet (v) Congenital malformation of heart.

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[29] What are the clinical features in Turner's syndrome?

Ans. The features are-

(i) External genitalia of female type but persons are chromatin negative, (ii) Short stature (iii) Webbed neck (iv) Low-set ears (v) Broad shield-like chest with widely spaced nipples and undeveloped breasts (vi) Small uterus and ovaries represented only by fibrous streaks.

[30] What are the clinical features of Klinefelter's syndrome?

Ans. The features are—

(i) External genitalia are of male type but persons are chromatin positive (ii) Testes very small (iii) Body hair spares (iv) Female-like breasts (v) Unusually long-legged.

EXERCISE

A Essay type: [1] What is Mendelism? What are the laws? Write briefly how Mendel made the experiment for dihybrid (Ans. 7.3, 7.5.3 & 7.5.4) [2] Describe the dihybrid cross experiment of Mendel and explain the laws as proposed by Mendel (Ans. 7.5.3 & 7.5.4) What is meant by dihybrid cross? With the help of checker board find out the phenotypic and genotypic 131 ratio of a dihybrid cross and mention the conclusion that Mendel has derived from it (Ans. 7.5.3) [4] (a) Who was Mendel? (b) What is meant by allele? (c) What is genetic material? (d) What are homozygous and heterozygous organism? (e) What do you mean by Phenotype and Genotype? (Ans. 7.3 & 7.5.2) [5] In man brown-eye (B) is dominant over blue-eye (b) A brown-eyed man marnes a blue-eyed woman and they have six children who have all brown-eyed. What are the genotypes of all the members of the material and an area (Ans. 7.11) family? Give reasons for your answer. [6] With the help of a chequer board show the numbers, ratio, phenotypes and genotypes which are found in Mendel's dihybrid cross. What did Mendel conclude from the results? (Ans. 7.5.3) [7] Comment on--(a) Hybrid, (b) Phenotype, (c) Dominant and recessive characters [8] Mendel took pollen from a pure dwarf pea plant and put it on the stigma of a pure tall pea plant. Only the tall plants were produced from the seeds of the dwarf plant (1st filial generation). Mendel then allowed self-fertilization amongst these tall plants and thus, both tall and dwarf plants were produced (2nd tihal . If HI I HADDERS E. " n, in est (4 hit) (a) State why all the plants were tall in the first filial generation? (b) What was the ratio of tall and dwarf plants in the second filial generation? (c) What inference did Mendel draw from this experiment on pea plants? [9] What are Mendel's laws? In Drosophila red eye is dominant over white eye. A red-eyed Drosophila is crossed with a white eyed one. Mention the genotype and phenotype of F, generation. [Tripura 1984], (Ans. 7.5.4 and 7.5.1) [10] (a) Waht is Mendel's principle of 'independent assortment'? (b) Distinguish between a phenotype and a genotype. (c) What kind of factor interaction is indicated when the phenotypic ratio 9.3.3:1 of the F₂ generation is [J.E.E. 1991], (Ans. 7.5.4, 7.5.2, 7.6) modified to 3:6:3:1:2:1? [11] Explain Mendel's law of independent assortment. [J.E.E. 1985, 1988], (Ans. 7.5.3) [12] What is the difference between recessive and dominant genes? Define homozygous and [J.E.E. 1988], (Ans. 7.5.2) [13] Give examples of modern findings which appear to contradict or cannot be fully explained by 20 0.107 . 10 10 15 16 [J.E.E. 1987], (Ans. 7.6) Mendel's law of Heredity. [14] (a) What is a test cross? (b) Tall tomato plants are produced by a dominant allele D and dwarf plants by its allele d. Hairy stems

are produced by a dominant allele H and hairless stems by its recessive allele h. A dihybrid tall hairy plant is test crossed. In the F, progeny there were 118 tall hairy, 121 dwarf hairless, 112

tall hairless and 109 dwarf hairy plants.

Short answer type:

What is genetics? Who first introduced this term?

■B.

(i) Represent the cross. [J.E.E. 1986], (Ans. 7.5.2, 7.11) (n) Find out the ratio of tall dwarf and hairy hairless [15] What is a gene? What is the difference between recessive and dominant genes? [J.E.E. 1987], (Ans. 7.5.2) [16] In man, brown eyes (B) are dominant over blue eyes (b) and dark hairs (R) dominant over red hairs (r). A man with brown eyes and red hairs marries a woman with blue eyes and dark hairs. They have two children, one with brown eyes and red hairs and the other with blue eyes and dark hairs. Give the [J.E.E. 1985], (Ans. 7.11) genotypes of the parents and children [17] (a) What is a dihybrid cross? Explain Mendels law of independent assortment. (b) Aa and Bb are two different alleles with A dominant over a and B dominant over b. Sketch the anaphase of first and second meiotic divisions and also the resulting gametes in the follpowing three cases to show their genic composition assuming that alleles Aa and Bb are carried. (1) In different pairs of homologous chromosomes $\begin{bmatrix} A \\ a \end{bmatrix}$ and $\begin{bmatrix} B \\ b \end{bmatrix}$ (11) In the same pair of homologous chromosomes AB ab with a crossing over in between Aa and Bb; and (iii) In the same pair of homologous chromosomes AB but without crossing over in between As and Bb loci (only sketch drawings are required) From your sketch, determine the cases which follow Mendel's law of independent assortment. Give [J.E.E. 1983], (Ans. 7.5.3, 7.5.4 and 7.11) [18] Who was G.J. Mendel? Give brief account of his contribution to science. [Tripura 1984], (Ans. 7.3) [19] (a) A blue-eyed man of whose parents were brown-eyed marries a brown-eyed woman. They have one child, who is blue-eyed. What are the genotypes of all the individuals mentioned? (b) What is phenotype" Mention which are phenotype in the above statement. [J.E.E. 1993], (Ans. 7.11, 7.5.2) [20] Mendel made a cross between a pea plant with yellow cotyledon and round seeds and one with green cotyledon and wrinkled seeds Consequently, the F, plants all had yellow cotyledon and round seeds. Then, he raised the F, generation by allowing self-fertilization between the F, plants. (a) What are the reasons for all the F, plants having yellow cotyledon and round seeds? (b) State how many types of F, plants were found and mention their ratios. (c) What did Mendel conclude from this experiment on pea plants? (Ans. 7.5.3) [21] Define genetics Mention the seven pairs of constrasting characters selected by Mendel Why did Mendel (Ans. 7.1., 7.5, 7.4.1) choose pea plants for his experiments? [22] (a) What are the reasons for all the F, plants having yellow cotyledons with round seeds in Mendel's (b) What inference did Mendel draw from dihybrid cross experiment in pea plants? [J.E.E. 1997], (Ans. 7.5.3) [23] With the help of a checker board explain Mendel's first law. [J.E.E. 1988], (Ans. 7.5.1) [24] What do you mean by dihybrid cross? Explain Mendel's law of Independent Assortment with the help (Ans. 7.5.3) of an experiment. [25] What is mutation? Describe the type of mutations that arise by change in chromosomal structure What do you mean by colour blind? A colour blind man has a normal brother and a colour blind sister, [26] Give the genotypes of the parents... What is genetic code? What are its different features. [Ans. 7.9] 1271 Describe in brief polypeptide synthesis in cukaryote 128 [29]

(Ans. 7.1, 7.14)

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		(Ama 282)
[2]	What is allele?	(Ans. 7.5.2)
[3]	What is phenotype?	(Ans. 7.5.2)
[4]	What are Mendel's laws?	(Ans. 7.5.4)
5	What is heterozygote?	(Ans. 7.5.2)
[6]	Why Mendel selected garden pea plant? Mention only two important por	nts. (Ans. 7.5.5)
[7]	Mention the names of the three biologists who redicovered the Mendel's	work. (Ans. 7.3)
[8]	Why Mendel's predecessors failed to deduce the laws of inheritance?	(Ans. 7.2)
[9]	What is monohybrid cross?	
[10]	What is dihybrid cross?	(Ans. 7.5.3)
[11]	What is back cross and test cross?	(Ans. 7.5.2)
[12]	What is Mendel's monohybrid ratio?	· (Ans. 7.5.1)
[13]	What is incomplete dominance?	(Ans. 7.6)
[14]	What is genotype?	(Ans 7.5.2)
[15]	Mention the seven pairs of contrasting forms of garden pea plant.	(Ans. 7.5)
[16]		[J.E.E. 1986], (Ans. 7.5.2)
[17]	What is an inter-allelic interaction of genes?	(Ans. 7.6)
[18]	What is supplementary genes?	(Ans. 7.6)
[19]	What is complementary genes ?	(Ans. 7.6)
[20]	What is epistasis?	(Ans. 7.6)
[21]	Explain briefly the following concepts:	(A== 2.5.4)
	Dominance, Law of segregation and Law of independent Assortment.	(Ans. 7.5.4)
• C.	Specific answer type :	
[1]	In which year Mendel published his experimental result on garden pea?	(Ans. 7.3)
[2]	In which year Mendel's work was rediscovered?	(Ans. 7.3)
[3]	Who proposed the 'fluid theory' of inheritance ?	(Ans. 7.2)
[4]	What are the peculiarities of the flower of garden pea?	(Ans. 7.4.1)
[5]	Mention the scientific name of garden pea.	(Ans. 7.5)
[6]	Who proposed the 'pangenesis theory'?	(Ans. 7.2)
[7]	Mention the length of a pure tall pea plant and a pure dwarf pea plant.	(Ans. 7.5.1)
[8]	What is the phenotypic monohybrid ratio of F, pea plant?	(Ans. 7.5.1)
[9]	What is the importance of test cross?	(Ans. 7.5.2)
• D.	Distinguish between:	
	· ·	[J.E.E. 1984], (Ans. 7.5.2)
[1]	Recessive and dominant genes.	[J.E.E. 1984], (Ans. 7.5.2) (Ans. 7.5.2)
[1] [2]	Recessive and dominant genes. Genotype and phenotype.	
[1] [2] [3]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote.	(Ans. 7.5.2)
[1] [2] [3] [4]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters.	(Ans. 7.5.2) (Ans. 7.5.2)
[1] [2] [3] [4] [5]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses.	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2)
[1] [2] [3] [4] [5] [6]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses. Dominance and incomplete dominance.	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.1, 7.5.3)
[1] [2] [3] [4] [5] [6] [7]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses.	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.1, 7.5.3) (Ans. 7.5.2, 7.6)
[1] [2] [3] [4] [5] [6] [7] [8]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses. Dominance and incomplete dominance. Epistatic gene and hypostatic gene.	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.1, 7.5.3) (Ans. 7.5.2, 7.6) (Ans. 7.6)
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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses. Dominance and incomplete dominance. Epistatic gene and hypostatic gene. Hybridization and hybrid. Back cross and test cross. Supplementary genes and complementary genes. Short notes:	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.1, 7.5.3) (Ans. 7.5.2, 7.6) (Ans. 7.6) (Ans. 7.5) (Ans. 7.5) (Ans. 7.5.2) (Ans. 7.5.2)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] • E	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses. Dominance and incomplete dominance. Epistatic gene and hypostatic gene. Hybridization and hybrid. Back cross and test cross. Supplementary genes and complementary genes. Short notes:	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.1, 7.5.3) (Ans. 7.5.2, 7.6) (Ans. 7.6) (Ans. 7.5) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.4)
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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] • E [1] [2] [3] [4] [5] [6] [7] [8]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses. Dominance and incomplete dominance. Epistatic gene and hypostatic gene. Hybridization and hybrid. Back cross and test cross. Supplementary genes and complementary genes. Short notes: Factor Allelomorphic pair Hybrid Phenotype Hybridization technique Test cross Gene interaction Linkage	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.3) (Ans. 7.5.2, 7.6) (Ans. 7.6) (Ans. 7.5) (Ans. 7.5.2) (Ans. 7.6) (Ans. 7.6.2)
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] • E [1] [2] [3] [4] [5] [6] [7] [8] [9]	Recessive and dominant genes. Genotype and phenotype. Homozygote and heterozygote. Dominant and recessive characters. Monohybrid and dihybrid crosses. Dominance and incomplete dominance. Epistatic gene and hypostatic gene. Hybridization and hybrid. Back cross and test cross. Supplementary genes and complementary genes. Short notes: Factor Allelomorphic pair Hybrid Phenotype Hybridization technique Test cross Gene interaction Linkage Incomplete dominance	(Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.3) (Ans. 7.5.2, 7.6) (Ans. 7.6) (Ans. 7.5) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.4) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.5.2) (Ans. 7.6) (Ans. 7.6) (Ans. 7.6) (Ans. 7.6) (Ans. 7.6)
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- [16] Sex-linked inheritance
- F Choose the Correct answer:

(Ans. 7.6.1)

- [1] Mendel's laws of inheritance was rediscovered in (1865/1900/1866
- [2] Mendel made experiment on (maize/wheat/garden pea)
- [3] In monohybrid, the phenotype ratio of offsprings in F, generation is (1.2.1/3.1/1.1)
- [4] In mendel's dihybrid cross the phenotype ratio of offsprings in F, is (9 3 3.1/9 3:4/9·7)
- [5] In monohyerid cross, the genotype ratio of offsprings in F, is (3:1/1:3/1-2:1)
- [6] In dihybrid cross, (2/5/6/4) types of phenotypic oftsprings are produced in F, generation.
- [7] Mendel's experimental results were published in the year of (1900/1866/1865)
- [8] Mendel considered (6/8/5/7) pairs of alleles in garden pea for his hybridization experiments

G. Fill in the blanks :

- [1] Mendel's classic work 'Experiments in plant hybridization' was published in the year -
- [2] Mendel selected — as the plant material for his experiments.
- [3] F. genotype ratio of monohybrid is -
- [4] In dihybrid F, plants produce types of gametes.
- [5] 9:3:3:1 is the ratio of cross.
- [6] Incomplete dominance occurs in a plant known as —
- [7] Genes in a chromosome are arranged in a order.
- [8] Gene is composed of like nucleic acid.

H. Put ✓ mark on Yes/No:

- [1] Incomplete dominance occurs in garden pea. Yes/No.
- [2] 'Pangenesis theory' of inheritance introduced by Aristotle Yes/No
- [3] Mendel conducted hybridization experiments for eight years Yes/No.
- [4] In 1900, Mendel's laws of inheritance were rediscovered. Yes/No.
- [5] Mendel made experiments on eight pairs of contrasting characters of garden pea. Yes/No.
- [6] Mendel's law of segregation is applicable university. Yes/No.

Answer to the Q. Nos. of F. G and H : -

- F. [1] 1900 [2] garden pea [3] 3·1 [4] 9 3 3 1 [5] 1 2 1[6] 4 [7] 1866 [8] 7
- G. [1] 1866 [2] garden pea [3] 1.2 1 [4] four [5] dihybrid [6] Mu abilis jalapa [7] linear [8] DNA.
- H. [1] No. [2] No. [3] Yes. [4] Yes. [5] No [6] Yes.

Taxonomy

Topics Discussed: Introduction, Definition and importance of taxonomy, Systematics, Types of taxonomy, Taxonomical hierarchy, Definition of taxon, Scope of taxonomy, Taxonomic key, aims and objectives, types and examples, Comparison between hierarchy and key, Binomial nomenclature, Codes of botanical nomenclature, Priority, Typification, Double citation, Trinomial nomenclature, Classification, Definition, Importance and forms of classification Basis of Classification, Phylogenetic classification, Vertical and Horizontal classification, Relationships of taxonomy with other branches of biology, Relationship of Taxonomy with classification, Outlines of plant classification including virus, bacteria, Mycoplasma, Actinomycetes, Spirochaetae and their salient features

8.1. Introduction

There are more than two millions plants and animals in the world. A large number of organisms have become extinct as a result of organic evolution through millions of years. At the sametime, a large number of plant and animal species have still remained obscure. It is very difficult to have a thorough, comprehensive knowledge about all these species unless they are properly arranged. This process of arranging the living species in a definite pattern is known as classification, while the branch of biology, which deals with the grouping of plants and animals is called taxonomy. The word 'taxonomy' comes from the Greek word Taxis = arrangement and nomos = laws. Thus taxonomy includes naming of organisms or nomenclature after its identification and classify them on the basis of their similarities and dissimilarities.

8.1.1. TAXONOMY

[1] **Definition : (Simpson, 1961)** It is the theoretical basis of classification including its principles, procedures and rules.

So, taxonomy helps in laying down the principles of classification and the two major aspects of taxonomy are nomenclature and classification.

- [2] Importance: [a] It gives detailed informations regarding the diversity of organisms.
- [b] It provides the necessary informations required in the other branches of biology.
- [c] It helps in determining phylogeny of organisms. (vertical classification).



Fig. 8.1: Basis of Taxonomy.

8.1.2. SYSTEMATICS

[1] **Definition: (G. S. Simpson, 1961):** It is the scientific study of diversity of organisms and their inter-relationships.

It is derived from the Greek word Systema and is referred to as the systems of classification by Linnaeus.

- [2] Importance: [a] A comprehensive study of an organism involving techniques and tools from other branches of biology.
 - [b] It helps to denote the diversity of organisms.
- [c] It helps to denote inter-relationship between two living species (horizontal classification).

8.2. Types of Taxonomy

The types of taxonomy are actually derived from the various stages of classification. They are as follows:

- [1] Alpha (α) Taxonomy: It is also called classical taxonomy; which involves description and naming of organisms. It is the parent of other types of taxonomy, denoted by Turrill (1943).
- [2] **Beta** (β) **Taxonomy:** In addition to morphological description, it also involves consideration of affinities and inter-relationship between separate groups of species.
- [3] Gamma (γ) Taxonomy: It is concerned with description, inter-relationship and evolution of one species from the other.
- [4] Omega (Ω) Taxonomy: It is the modern experimental taxonomy denoted by **Epling** (1943), in which the taxonomic endeavours have been enriched with data from coology, phytogeography, phytochemistry, cytogenetics and physiology coupled with adequate computation.

8.2.1. TAXONOMIC HIERARCHY

[1] **Definition**: The taxonomic hierarchy is a systematic framework of classification in which the taxonomic groups are arranged in a



Fig. 8.2: Carrolus Linnaeus (1707-1778).

definite order from higher to lower groups and each of them excepting the lowest one includes the subordinate groups.

[2] History: The hierarchic system of classification was first adopted by Carrolus Linnaeus

- classification was first adopted by Carrolus Linnaeus in 1753 in the 10th edition of "Systema Naturae". This was called Linnaean hierarchy and the succession of groups is as follows:
- (i) The lowest major group, representing plants and animals is referred to as Species.
- (ii) The closely related species of plants and animals are placed in Genus.
- (iii) The related genera of plants and animals constitute a Family.
- (iv) The families together are placed in Orders.
- (v) The orders of plants and animals constitute Classes.
- (vi) The classes together constitute Division in plants and Phylum in Animals.

(vii) Finally, the divisions or phyla together constitute a Kingdom.

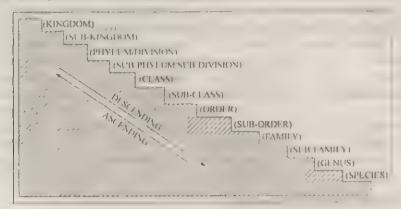


Fig. 8.3 : Taxonomical Hierarchy

The taxonomic divisions indicated by Linnaeus show that the Kingdom or Phylum is the largest division, while the species is the smallest division and they are also represented in window-pane model.

[3] Modern view of Hierarchy: The present day taxonomists have shown slight deviation from the Linnaean system of

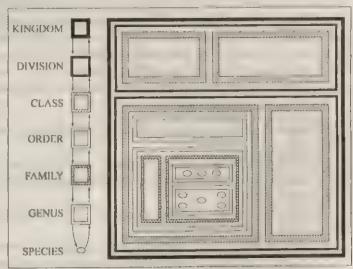


Fig. 8.4: Window-pane Illustration of Taxonomic Units.

Hierarchy. The diversity of plants and animals have also increased with the reporting of new species and the seven taxonomic groups seems to be inadequate in the present day context, so newer groups like sub-species, cohorts have been created and each of the existing groups has been further sub-divided using prefixes like super, sub or infra etc. Simpson (1945) showed the present day taxonomic groups used to denote higher group of animals like mammals and they are as follows:

Kingdom	Cohort	Sub-family
Phylum	Super order	Tribe
Sub-Phylum	Order	Sub-Tribe
Super Class	Sub-order	Genus
Class	Infra order	Sub-Genus
Sub-Class	Super Family	Species
Infra Class	Family	Sub-species

Each of these groups is called **Taxon**. The definition of taxa will be: A group of related organisms recognised as a unit at any level of taxonomic hierarchy.

[4] Systematic Position following Taxonomic Hierarchy:

Animal: Homo sapiens (Human) Plant: Lantana camara (B. Chota) Animalia Kingdom: Plantae Kingdom: Spermatophyta Chordata Phylum: Division: Mammalia Angiospermae Class: Sub-division: Dicotyledonae Primate Order: Class: Hominidae Verbenales Family: Order: Homo Genus: Family: Verbenaceae Species: sapiens Genus: Lantana . Species: camara

8.2.2. SCOPE OF TAXONOMY

Taxonomy is one of the oldest science, reaching back to more than 200 years in the ancient Greece and Rome. It provides thorough knowledge of living species and their various forms. Every branches of biology is dependent on it because it provides proper identification of the species. Present day taxonomy has proceeded further, incorporating data from phytochemistry, cytogenetics supported by adequate computation, which has made it easier to trace the evolution of particular species and their actual point of origin. Lastly the taxonomic research has also facilitated the conservation of biodiversity.

8.2.3. TAXONOMIC KEY

A taxonomic key is an analytical device for the determination of the names of plants included in it.

- [1] **Definition of Key**: It is a systematic framework for tabulation of organism with a sequence of classes at each level and gradually deriving more restricted classes from broader groups.
- [2] Objective of Key: [a] To segregate the characteristic features of individual species for easy identification.
 - [b] It is an useful tool for identification of unknown species.
 - [c] It gives a detailed account of the species present in a particular class.
- [3] Types of Keys: There are two types of keys, which are, Indented Key and Bracketed Key.
- [A] Indented Key: The common character is written at the outset and then the two species are identified on the basis of their individual characters.

e.g.: Identification of Primula farinosa and P. scotia.

Leaves mealy beneath; flowers lilac or purple.

Leaves not mealy beneath, flowers yellow.

- [B] Bracketed Key: This Key is represented by a pair of contrasting characters from which the species are identified.
- e.g. The illustration is based on the same four species of Primula as considered earlier.

 - [II] Leaf edge crinkly, flowers lilac; calyx teeth pointed, fruit cylindrical

(1) Primula farinosa.

[IV] Calyx pale green, fruits egg-shaped, enclosed in calyx (3) P. veris.

Calyx with darker mid-ribs, fruits elongated; projected from calyx [4] P. elatior.

8.2.4. COMPARISON BETWEEN KEY AND HIERARCHY

Points of Differences	Hierarchy	Key
[1] Nature:	[1] The classification based on taxonomic hierarchy is natural.	[1] The classification based on taxonomic key is artificial.
[2] Basis : Property is	[2] It is based on natural relationships.	[2] It is often based on arbitrary sequences.
[3] Priority: - sh	[3] It obeys the principle of priority.	[3] It does not obey principle of priority.
[4] Sequences:	[4] The groups normally follow an orderly sequence.	[4] The groups do not follow an orderly sequence always as in case of Bracketed Key.
[5] Constituent:	[5] Each of the lower groups normally belong to a single higher group.	[5] The lower group may belong to two or more higher groups.
[6] Example:	Mammals Horned Two-toed mammals mammals	Homed Mammals Animal Homed Two-toed mammal Two-toed mammal Two-toed mammal

8.3. Nomenclature: (Latin: Nomen = name; calere = to call)

The term 'nomenclature' means call by name and it actually includes the method of naming plants and animals. This name should be universally accepted in all countries since the common name of plants and animals may be different in different languages. Carrolus Linnaeus started giving these names in his own vernacular language *i.e.*, Latin and later this was accepted universally because Latin is not the officially spoken language. Otherwise.

[1] **Definition**: Nomenclature is a term which determines the correct scientific naming of an identified species of plants or animals according to an established system.

8.3.1. BINOMIAL NOMENCLATURE: (Bi = two; Nomen = names)

This type of nomenclature was first proposed by **Linnaeus** in his book entitled "Species Plantarum". These names had two parts, the generic name and the specific name. For e.g. banyan will be written as Ficus benghalensis L. and Lion will be written as Panthera leo L. So, it is evident that names should be written in italics when printed, the generic epithet should commense with capital letter, while the specific epithet should be in small latter. When hand written, they should be underlined, the name of the author, who first reported the species should be at the end the scientific name in abbreviated form, that is for Linnaeus, it is given as "L". This system of nomenclature is known as binary system.

[1] **Definition:** The system of scientific naming of a species of plant or animal using genera as the first part and species as the second part is known as Binomial Nomenclature.

8.3.2. INTERNATIONAL CODES OF BOTANICAL NOMENCLATURE (ICBN)

The first organized effort was made in 1867 in Paris, where 150 European and American botanists met and de Candolle's "Lois de la nomenclature botanique (Laws of Botanical Nomenclature) was discussed. The principles emerged out as Paris Code, in which the starting point of plant nomenclature was from Linnaeus, the Kew rule was also formulated here. Subsequently, the Rochester Code came up in 1872, which gave maximum stress on priority, the Vienna Code in 1905, Brussels Code in 1910, Cambridge Code in 1930, Stockholm Code in 1950, Sydney Code in 1983, Tokyo Code, 1994, the St. Louis Code in 1999 and the Vienna Code, 2005. Each of these codes discussed about the principles of plant nomenclature and the resolutions adopted were incorporated in the next edition of "Laws of Plant Nomenclature" and thus the rules of nomenclature was modernized. The final form of plant nomenclature rule was finalized in 1966, the animal nomenclature rules were adopted in 1961 as per the recommendations of ICZN (International Code of Zoological Nomenclature).

8.3.3. MAJOR RULES OF BINOMIAL NOMENCLATURE

Some major aspects of Binomial Nomenclature are as follows:

- [1] The scientific names of plants and animals should be in Latin because it is not the official language of any country.
- [2] The scientific names prior to the publication of *Systema Naturie* (10th Edition) by **Linnaeus** were all rejected.
- [3] The names should be specific and should at least have the generic and specific epithet.
- [4] These names should be in italics when printed, or underlined when written by hand.
 - [5] The genus starts with capital letter, while species in small letter.
- [6] The name of the author, first reporting it should remain in abbreviated form at the end of the scientific name.
- [7] The reporting of a new species of plant should be accompanied by a Latin description or diagnosis.
 - [8] Only one valid name for one species is permitted and it is based on the rule of

priority, that is the author first effectively and validly publishing the name, will be considered.

[9] In case of changing a scientific name, that is **double** citation, the name of the second author is placed in bracket after the scientific name and the first author's name in abbreviated form comes after that. The new name is always based on the older name and it is called the **basionym**.

[10] When a plant is reported, the author should submit a herbarium specimen of the same. (dried plant with reproductive part placed on a sheet of paper). This is designated as the **Holotype**. All the other specimens collected by the author at that time is known as **Lectotype**. In case of their destruction, the same specimen collected by a different author from the same location is known as **Paratype**. If the specimen is reported by a new author from a new location at a different time, then that is known as **Neotype**. This concept is known as typification and the type specimens should be preserved in the harberia of all international botanic gardens.

8.3.4. SUB-SPECIES CONCEPT AND TRINOMIAL NOMENCLATURE

The binomial nomenclature is widely accepted and it helped in the correct identification of species. But for very large groups of plants and animals, it became inadequate because there were variations even within species. Hence **Mayer** (1953) denoted the concept of **sub-species**, which meant geographically defined aggregates of local populations. It was also incorporated in the scientific name and gave rise to **trinomial nomenclature**. e.g. Homo sapiens neanderthales; Homo sapiens sapiens.

8.3.5. SCIENTIFIC NAMES OF COMMON PLANTS AND ANIMALS

PLANTS			ANIMALS		
Common Name Scientific Name (Binomials)		Cor	nmon Name	Scientific Name (Binomials)	
1.	Rice .	Oryza sativa	1.	Amoeba , ,	Amoeba proteus
2.	Maize	Zea mays	2	Paramoecium	Paramoecium caudatum
3.	Wheat	Triticum aestivum	3.	Hydra	Hydra vulgaris
4.	Coconut	Cocos nucifera	4.	Tapeworm	Taenta solium
5.	Pea	Pisum sativum	5.	Roundworm	Ascaris lumbricoides
6.	Gram	Cicer arietinum	6.	Earthworm	Pheretima posthuma
7.	Touch me not	Mimosa pudica	7.	Cockroach	Periplaneta americana
8.	Rubber	Hevea brasiliensis	8.	Prawn	Palaemon carcinus
9.	Mango	Mangifera indica	9.	Apple snail	Pila globosa
10.	Rose	Rosa centifolia	10.	Starfish	Asterius rubens
11.	Banyan	Ficus benghalensis	11.	Rohu fish	Labeo rohita
12.	Potato	Solanum tuberosum	12.	Catla fish	Catla catla
13.	Tomoto	Lycopersicum esculentum	13.	Magur fish	Clarius batracus
14.	Chinarose	Hibiscus rosa-sinensis	14.	Singhi fish	Heteropneustes fossilis
15.	Ladies finger	Abelmoscus esculentus	15.	Toad	Bufo melanosticius
16.	Jute	Corchorus capsularis	16.	Frog	Rana tigrina
17.	Akanda	Calotropis procera	17.	Cobra	Naja naja
18.	Periwinkle	Catharanthus roseus	18.	Guineapig	Cavia porcellus
19.	Tulsi	Ocimum sanctum	19.	Dog	Canis familiaris
20.	Snap dragon	Antirrhinum majus	20.	Tiger	Panthera tigris
21.	Sun flower	Helianthus annus		Leopard	Panthera pardus
22.	Marigold	Tagetes patura		Human	Homo sapiens

8.4. Classification

- [1] **Definition:** Classification is defined as the ordering or ranking of organisms into groups on the basis of similarities or closeness or relationship. Since there are large number of plants and animals, so it is easier to study them after they are arranged in small or large groups.
- [2] Forms of Classification: There are two distinct forms of classification, which are as follows:
 - (i) Classification of Overlapping sequences or Keys.
 - (ii) Classification following Taxonomical hierarchy.
 - [3] History of Classification:
- (i) Aristotle (384-322 B.C.) divided animals into two groups viz. Anaima without red blood e.g. sponge, Hydra. Enaima with red blood e.g. fish, frog, birds.
- (ii) Theophrastus (371-287 B.C.) divided plants as herbs, undershrubs, shrubs and trees.
 - (iii) John Ray (1627-1705) divided plants into Herbae and Arborea.
- (iv) Carrolus Linnaeus (1707-1778), the Swedish naturalist gave the classification of plants in "Species Plantarum" in 1758 and that of animals in "Systema Naturae (10th Ed.) in 1753.
 - (v) Lamarck (1744-1829) gave the animal classification.
- (vi) **De Candolle** (1778-1841) in 1813 gave the natural system of classification and proposed the term taxonomy.
- (vii) George Bentham (1800-1884) and J. D. Hooker (1862-1883) gave the natural system of classification in 3 volumes of Genera Plantarum.
- (viii) Adolf Engler (1844-1930) and Karl Prantl (1849-1893) gave the phylogenetic system of classification in 1886-1892 in 20 volumes of **Die Natürlichen Pflanzen Familien.**



Fig. 8.5 : George Bentham (1800–1884)



Fig. 8.6 : Adolf Engler (1844–1930)



Fig. 8.7 : John Hutchinson (1884–1974)

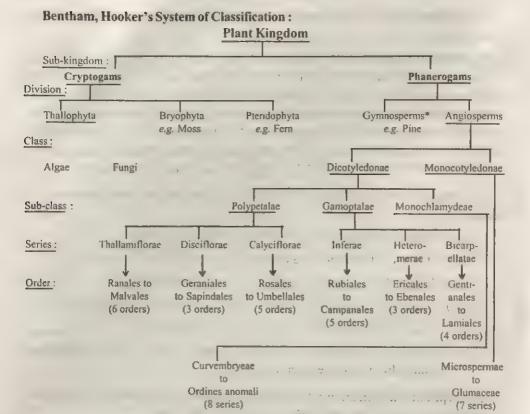
(ix) John Hutchinson (1884-1978) in 1926, 1934 and in 1950 gave the modern phylogenetic classification in 3 volumes of "The families of flowering plants".

- (x) Takhtajan (1967) and Cronquist (1968) also gave the modern phylogenetic classification.
- [4] Basis of Classification: [i] Classification initially was based on superficial morphological characteristics. [ii] With the development of natural system of classification, the morphologlical characteristics were considered in every minute detail, along with that, there was also consideration of the reproductive features. (iii) The phylogenetic system of classification considers the gradual evolution of organisms and their phylogenetic relationships. (iv) The modern system considers all the relevant data from other branches of biology and it is developed by adequate computation.
- [5] Purposes of Classification: The different purposes of classification are as follows:
 - (i) It helps in the arrangement of living plants and animals.
 - (ii) It is a tool for identifying organisms.
 - (iii) It provides explanation for the diversity of organisms.
 - (iv) It gives adequate knowledge of evolution or phylogeny of organisms.
 - (v) It gives a provision for the discovery of new species.
 - (vi) It helps in the storage of date about living organisms in the form of key and utilize them whenever necessary.
- [6] **Types of Classification:** The classification system are mainly of three types *viz.* **Artificial, Natural, Phylogenetic** system of classification.
- [A] Artificial system: This system is only based on one or two superficial characters without considering any morphological details or phylogenetic relationships.

For example, the classification of animals by Aristotle on the basis of colour of blood that is **Anaima** without red blood *e.g.*-sponges and **Enaima** with red-coloured blood. Linnaeus classified plants as *Monandria* (one stamen) and *Diandria* (two stamens).

Demerit: (i) Closely related species may be placed distantly apart and distant species might be placed together. (ii) The evolutionary relationships were not understood.

- Merit: (i) First novel attempt of classifying living organisms and hence they have some historic importance.
- [B] Natural system: The system of classification is based on several natural characteristics. In this system the simplest organisms are placed early, while the complex ones are placed later. This system relied on the constancy of species. The system was proposed by George Bentham and Joseph Dalton Hooker in three volumes of Genera Plantarum published between 1862 and 1883. In this system, several morphological characters were taken into consideration, so it is widely accepted and plants are arranged according to this system in many botanic gardens. An outline of this system is given below:



- * Considered between Dicotyledonous and Monocotyledonous Plants.
- **Demerits**:(i) Gymnosperms were wrongly placed between dicotyledonous and monocotyledonous plants.
 - (ii) There was no phylogenetic considerations.
 - (iii) Some of the closely related species are placed distantly, while distant species are placed close to each other.
- Merits: (i) It gave an easy means of identification of unknown plants.
 - (ii) The authors actually studied the morphological characters of plants before placing them in their respective positions.
 - (iii) An original novel attempt describing 97, 205 species and hence was widely accepted.
- [C] Phylogenetic system: This system is based on evolutionary sequence and the genetic relationships are considered.

The system was actually developed after the publication of Darwin's theory in 1859 and in this system, along with the natural morphological characteristics, inputs from fossil records, genetic constitutions were also considered and hence it is largely accepted by modern biologists.

Adolf Engler and Karl Prantl (1886-1892) published a series of 20 volumes of "Die Natürlichen Pflanzen Familien" in which they divided higher plants into 3 major divisions and had suggested the evolution of flowering plants from extinct fossil gymnosperms. John Hutchinson (1950) gave his final form of classification in "The

Families of Flowering Plants" He divided flowering plants into Herbaceae (small plants) and Lignosae (big trees), his classification was based on 22 important considerations. Dicotyledonous plants were considered more primitive than monocotyledonous plants. Amongst the Herbaceae, Ranales was the primitive order, while Asterales was advanced. In Lignosae, Magnoliales was primitive, while Verbenales was advanced.

In recent times **Takhtajan** (1967) and **Cronquist** (1968) have also given well documented classification system.

Demerits: (i) Not quite suitable for practical purpose though these defects are removed in recent classifications.

Merits: (i) Give the phylogenetic relationship.

- (ii) Has resulted in the development of experimental taxonomy.
- (iii) Has the systemic thoroughness and is widely accepted.

8.4.1. MINOR UNITS OF CLASSIFICATION

The lowest unit of hierarchic system of classification is species, which aggregate together to form genus and the related genera form the families. These three constitute the minor unit of classification.

- [a] Species: They are defined as the smallest group of potentially interbreeding natural population, which are reproductively isolated from other groups. They are the second epithet in a scientific name. The reproductive isolation is the most important character, if the individuals of one species breed with other species, then sterile individuals are produced. These species are usually morphologically distinct and can be identified on the basis of the physiological behaviour and habitat, which are as follows:
- (i) **Sibling species**: The species are morphologically similar but physiologically different *e.g.* The female *Anopheles* look alike but only some carry the malarial parasite.
- (ii) Allopatric species: The same species occupy different geographical habitat due to continental drift and ultimately develop reproductive isolation or structural variation. e.g. African and Indian Lion.
- (iii) Sympatric species: The two different species sharing the same habitat and having similar nutritive habits. e.g. Entamoeba and Ascaris remaining in the small intestine of human beings.
- (iv) Genus: It is defined as taxonomic group formed of closely related species resembling in their reproductive characteristics. They represent a noun and remain as the first epithet of a scientific name. As per the ICBN, it always begins with capital letter.
- [b] Family: It is a taxonomic group formed of related genera which may have some broad resemblances.

The plant families mostly end with "ceae", like Verbenaceae, Solanaceae etc. Animal families may end with "dae" like Hominidae (human family); Bufonidae (frog family). They are not a part of scientific name.

8.4.2. VERTICAL AND HORIZONTAL CLASSIFICATION

Vertical classification and Horizontal classifications are the recent trends of classification. Vertical classification indicates the evolution of the present day plants

Name of the Order	Common Name	Major Characters	Example
3 Beggiatoales	Filamentous sulphur bacteria	Chains of colourless cells with gliding movement, include saprophytes and parasites; reproduce by fission.	Beggiatoa.
[4] Caryophanales	Filamentous Sheathed bacteria	Chains of colourless cells with disc-like nuclear bodies, habitat is in the intestine of animals and also in decomposed organic matter containing water,	Caryophanon, (Grows in cow dung).
5 Chlamydo- bacteriales	Filamentous Iron bacteria	Chains of colourless cells, ensheathed in mucilage containing iron oxide, reproduces by fragmentation or by producing motile asexual spores.	Sphaerotilus.
[6] Hyphomicro- biales	Budding- bacteria.	Unicellular, saprophytic or sometimes photosynthetic in nature, reproduce by the produc- tion of buds arising from the end of the stalk.	Hyphomicrobium, Rhodomicrobium.
[7] Myxobacteria.	Slime bacteria.	External slime layer for protection and creeping movement, cell wall is flexible, unicellular, forms fruiting bodies, microcysts and saprophytic in nature.	Cytophaga (Cellulose decomposing bacteria).
[8] Actinomyce- tales.	Actinomycetes.	Branched filaments, reproduce by fragmentation and fission and also by producing conidia.	Streptomuces, Mycobacterium,
[9] Mycopias-	Pleuro pneumo- nia like organism (PPLO).	Flexible cell wall, pleomorphic filamentous or small elementary bodies, saprophytic or parastitic in nature, passes through bacterial filters.	Mycoplasma (Causes pleuro- pneumonia in cattles).
[10] Spirochae- tales.	Spirochaetes.	Long helical cells with flexible wall, exhibits squirting movements, saprophytic or parasitic in nature.	Treponema, Borrelia, Leptospira.

8.6.3. ALGAE

The first detailed classification of algae was given by Fritsch (1945), where he divided the group into 11 classes.

They are as follows:

- (i) Chlorophcease (green algae) consisting of 9 orders. e.g. Volvox.
- (ii) Xanthophyceae (yellow green algae) consisting of 4 orders. e.g. Vaucheria.
- (iii) Chrysophyceae (golden brown algae) consisting of 3 orders. e.g. Chromulena.
- (iv) Bacillariophyceae (diatoms) consisting of 2 orders. e.g. Fragilaria.
- (v) Cryptoplyceae (cryptomonads) consisting of 2 orders. e.g. Hillea.
- (vi) Dinoplyceae (dinoflagellates) consisting of 6 orders. e.g. Desmocapsa.

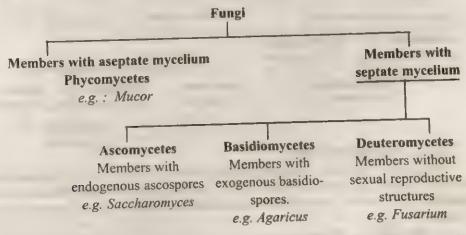
- (vii) Chloromonodineae (chloromonads) consisting of a single order. e.g. Trentonia.
- (viii) Euglineae (exglenoids) consisting of single order. e.g. Euglena.
 - (ix) Phaeophyceae (brown algae) consisting of 9 orders. e.g. Ectocarpus.
 - (x) Rhodophyceae (red algae) consisting of 6 orders. e.g. Polysiphonia.
 - (xi) Myxophyceae (blue green algae) consisting of 5 orders. e.g. Nostoc.

Bold and Ynne (1978) gave a recent classification, where algae was divided into 9 divisions. They named all the groups as phyco (≡ algae) phyta excluding the procaryatic blue green algae. The classification is as follows:

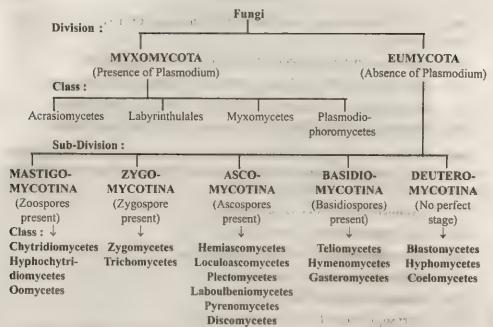
- [i] Cyanochoronta (Blue Green algae)
- [ii] Chlorophycophyta (Green algae)
- [iii] Charophycophyta (Dendrobial green algae)
- [iv] Euglenophycophyta (Euglenoids)
 - [v] Phaeophycophyta (Brown algae)
- [vi] Chrysophycophyta (Golden brown algae)
- [vii] Pyrrhophycophyta (Dinoflagellates)
- [viii] Cryptophycophyta (Cryptomonads)
- [ix] Rhodophycophyta (Red algae)

8.6.4. FUNGI

The first major classification of fungi was provided by **Gwynne-Vaughan** and **Barnes** (1937), in which fungi was divided into 4 major classes and myxomycetes was not included in fungi. The outline of this classification is as follows:



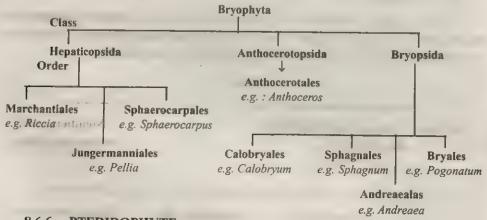
J. Webster (1980) gave the most recent classification, in which fungi was divided into Myxomycota and European, the former was directly divided into four classes, while the latter was divided into 5 sub-divisions and 17 classes, as detailed below:



8.6.5. BRYOPHYTE

The bryophytes include a group of amphibious plants, which can survive both in land and water.

Eichler (1883) for the first time divided bryophytes into 2 classes, Hepaticeae and Musci. **Parihar** (1965) gave a detailed classification of bryophytes and it is as follows:



8.6.6. PTERIDOPHYTE

This group of plants are known as the first terrestrial vascular plants because they have true xylem and phloem. **Smith** (1955) gave the most detailed classification of pteridophytes, where it was divided into 4 divisions, 4 classes and 17 orders. It is as follows:

1, Division I: Psilophyta

Class I Psilophytinae.

Order II Psilophytales (fossil).
Order II Psilotales (Psilotum).

Division II: Lepidophyta

Lycopodinae. Class II

: Lepidodendrales (fossil). Order III · · · Lycopodiales (Lycopodium). Order IV Selaginellales (Selaginella). Order V

Isoetales (Isoetes). Order VI

Calamophyta Division III: 3.

Equisetinae. Class III

Hyeniales (fossil). Order VII

: Sphenophyllales (fossil). Order VIII Order IX Equisetales (Equisetum).

Pterophyta Division IV: 4.

Filicinae. Class IV Primofilicales. Sub-class I

Archeopteridales (fossil). Order X : Protopteridales (fossil). Order XI Coenopteridales (fossil). Order XII

Eusporangiatae (Sporangia borne in sori). Sub-Class II

Marattiales (Marattia). Order XIII

Ophioglossales (Ophioglossum). Order XIV

Leptosporangiatae (Sporangia borne in sori). Sub-Class III

Marsileales (Marsilea). Order XV Salvineales (Salvinea). Order XVI Filicales (Dryopteris). Order XVII

8.6.7. GYMNOSPERMS

The gymnosperms belong to a group of plants which are naked seeded. D. D. Pant (1979) gave a comprehensive classification of gymnosperms, in which the group was divided into 3 divisions and 9 classes. The classification is as follows:

Division I: Cycadophyta

Class 1: Pteridospermospida—6 orders: Lyginopteridales to Caytontiales (all fossil members).

— Order –Cycadales-e.g.: Cycas. Class 2: Cycadopsida - Order-Pentoxylales (fossil). Class 3: Pentoxylopsida Order—Cycadeoidales Class 4: Cycadeoideopsida

Division II: Coniferophyta [2]

 Order —Cordaitales (fossil). Class 5: Coniferopsida Order-Coniferales-e.g. : Pinus.

Order-Ginkgoales-e.g. Ginkgo.

- Order -Ephedrales. e.g. Ephedra. Class 6: Ephedropsida - Order-Czekanowskiales (fossil). Class 7: Czekanowskiopsida

- Order-Taxales e.g. Taxus. Class 8: Taxopsida

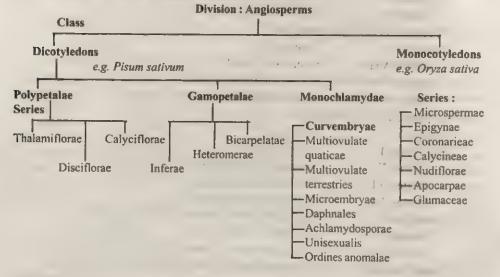
Division III: Chlamydospermophyta [3]

- Order-Gnetales e.g. Gnetum. Class: Gnetopsida Order-Welwitschiales

e.g. Welwitschia.

8.6.8. ANGIOSPERMS

The angiosperms or the flowering plants are the highest evolved organisms in the plant kingdom. G. Bentham and J. D. Hooker (1862—1883) divided angiosperms into 200 families and the broad divisions are as follows:



8.7. Diagnostic features of different plant groups

- (1) Virus:
- (i) The body of virus is formed of nucleic acid and protein.
- (ii) They can only replicate within specific host.

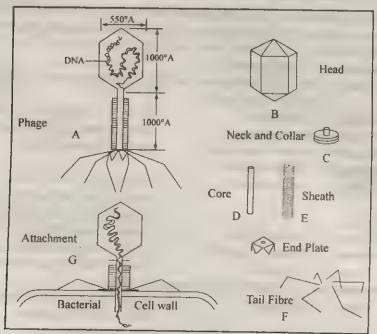


Fig. 8.8: Bacteriophage.

- (iii) They have the ability to produce bacteriocidal compound lysozyme like higher animals.
- (iv) They lack nucleus and other cell organelles.
- (v) They lack life processes like respiration, metabolism and excretion.
- (vi) They possess high specific gravity like inorganic substances.
- (vii) They can be drawn into crystals at very low temperatures.
 - (viii) They do not respond to external stimuli.
 - (ix) They do not grow in synthetic cultures.
 - (x) They have the ability to show mutation.

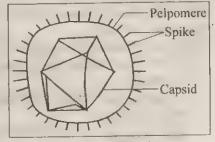


Fig. 8.9: Herpes virus.

The useful viruses are bacteriophage which destroy bacteria while the attenuated strain of polio virus is used in the preparation of vaccine.

(2) Bacteria:

- (i) They are unicellular prokaryotic organisms.
- (ii) They may be parasitic, saprophytic, photosynthetic or symbiotic in nature.
- (iii) The cell wall is non-cellulosic in nature, commonly consists of peptidoglycan.
 - (iv) The nucleus is devoid of nuclear membrane.
 - (v) The respiration is brought about by mesosome.
- (vi) The photosynthetic pigment remains stored in the chromatophores.
 - (vii) The ribosomes are 70 S in nature.
 - (viii) They divide by amitosis.
- (ix) The asexual reproduction takes place by endospore formation.
- (x) The sexual reproduction in bacteria takes place by conjugation, transformation and transduction.

Useful bacteria :

Bacillus subtilis produces antibiotic bacitracin; Agrobacterium tumefasciens produces Ti plasmids useful in genetic engineering.



- (i) The organism may be unicellular, filamentous, colonial or dendrobial in nature.
- (ii) It can be prokaryotic (blue green algae) or eukaryatic in nature.
- (iii) The pigments are of various types *i.e.*, blue green-cphycocyanin, red-r-phycocrythrin, green-chlorophyll, brown-fucoxanthene, yellow-xanthophyll molecules.
 - (iv) The cell wall is cellulosic in nature.
- (v) The flagella is eukaryotic in nature *i.e.*, it contains (9+2) microtubules.

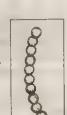


Fig. 8.10: Streptococci.



Fig. 8.11: Spirillum.

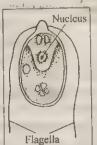


Fig. 8.12: Chlamydomonous.

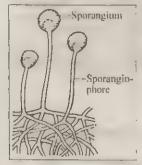


Fig. 8.13 : Spirogyra filament.

- (vi) The sex organs are multicellular with a sterile jacket.
- (vii) There is no embryo formed, the zygote immediately undergoes meiosis and forms the haploid plant body.
- (viii) They may be aquatic (fresh water and marine), terrestrial, epiphytic, parasitic or endophytic in nature.
 - (ix) They reproduce by vegetative, asexual and sexual means.
 - (x) The major storage food is starch and cyanophycean starch.

(4) Fungi:

(i) The fungi are heterotrophic organisms devoid of chlorophyll, either saprophytic or parasitic in nature.

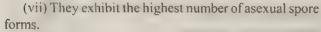


(ii) They may be unicellular or multicellular, formed of filamentous structures called mycelia or hyphae.

- (iii) The cell wall consists of different polysaccharides, including a nitrogenous polysaccharide called chitin.
- (iv) They are always eukaryotic in nature, though chloroplast is absent.
- (v) It is without green pigment chlorophyll, but non-green pigment like violet neo-cercosporin, orange coloured carotene present.

(vi) They reproduce vegetatively by fission, fragmentation

Fig. 8.14: Mucor. and budding.



- (viii) The sexual reproduction is by syngamy, fertilization.
- (ix) The stored food is glycogen, mannitol, but never starch.
- (x) The life cycle is divided into haploid and diploid phases, though an intermediate (n+n) dikaryotized stage may be present in certain fungi (Basidiomycetes).

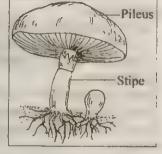


Fig. 8,15: Agaricus.

(5) Bryophyte:

(i) The plants are amphibious in nature.



Fig. 8.16: Riccia.

- (ii) The plant body may be thalloid or leafy in nature.
- (iii) The gametophytic plant body is prevalent and the sporophyte is dependent on the gametophyte.
- (iy) The antheridia are the male reproductive organ, which is club shaped in nature producing the

biflagellate antherozoids.

- (v) The female reproductive organ is archegonia, which is flask shaped with a swollen venter containing egg and ventral canal cell and a long neck containing neck canal cell.
- (vi) The antherozoids move towards archegonium by chemotaxism.



Fig. 8.17: Pogonatum.

(vii) The sporophyte is differentiated into foot, seta and capsule.

- (viii) The capsule shows progressive sterilization of sporogenous tissue.
 - (ix) Spore dispersal method is noted in higher forms of bryophytes.
- (x) The conducting tissue is absent in the thalloid form, but present in the leafy forms in the form of thick walled hydrome and thin walled leptome.

(6) Pteridophyte:

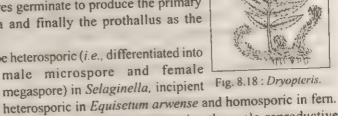
(i) They belong to a group of plants called vascular cryptogams because they have true xylem and phloem tissue.

(ii) The life cycle shows alternation between sporophytic and gametophytic forms, both sporophyte and gametophyte are independent of each other.

(iii) The spore bearing structures are sporangia, which may be either borne by the strobilus or by the sorus.

(iv) The haploid spores germinate to produce the primary or secondary protonema and finally the prothallus as the gametophytic plant body.

(v) The spores may be heterosporic (i.e., differentiated into



Pinnae



Fig. 8.19: Equisetum.

(vi) The gametophyte contains the male reproductive

structure antheridia, which is globose and produces the multiflagellate antherozoids.

(vii) The female reproductive organ is archegonia, which is flask shaped with a very short neck and venter.

(viii) Fertilization is within the archegonium.

(ix) The gametophyte contains chlorophyllous cells and so can prepare its own food.

(x) There may be scales, smooth walled and tuberculate rhizoids present in the gametophyte.

(7) Gymnosperm:

(i) The plants are naked seeded.

(ii) The stem shows massive secondary xylem without vessel.

(iii) The leaves may be scaly, needle shaped or with a broad lamina.

(iv) The roots are invested with mycorrhizal fungi.

(v) The reproductive structures are borne in male and female strobilus.

(vi) The male gametophyte is represented by pollen grains, disseminated by wind at 4 or 5 nucleated stage.

(vii) The female gametophyte is formed within the naked

(viii) The endosperm is haploid in nature formed within the ovule before fertilization. And a

(ix) The phenomenon of polyembryony is commonly seen in many of the members.

(x) The seed dispersal method is usually absent, they usually germinate, when the female cone falls on to the ground.



Fig. 8,20: Pinus.

(8) Angiosperms:



Fig. 8.21 : Paddy : monocot plant.

- (i) They are flowering plants.
- (ii) Seeds are borne within the fruit.
- (iii) The plants may be monocotyledonous or dicotyledonous on the basis of the number of cotyledons present in the seed.
 - (iv) The stem shows secondary xylem with xylem vessels.
- (v) The roots may be tap root system or fibrous root system.
- (vi) The leaves have broad lamina, which may be with parallel or reticulate venation.
- (vii) The complete flowers have 4 whorls, which are calyx, corolla, androecium and gynoecium.
 - (viii) They usually exhibit

double fertilization, i.e., endosperm is triploid in nature formed after fertilization.

- (ix) Polyembryony is usually absent.
- (x) There is well developed fruit and seed dispersal method.



Fig. 8.22: Chinarose: dicot plant.

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8.8. Some economically important plants

8.8.1. ALGAE: Spirulina.

[1] Systematic Position: (Fritsch, 1945)

Class: Myxophycleae
Order: Nostocales

Family: Oscillatariaceae Genus: Spirulina

Indian species: S. platensis, S. pacifica.

- [2] General Characters: The plant body is a filamentous blue green algae, not divided into cells, but appear as an undifferentiated filament. It is enriched in protein, carotene pigment, γ linolenic acid. It is cultivated at high pH mostly during summer season. The protein content becomes maximum in 2 weeks time.
 - [3] Useful part: The entire plant body is useful.
 - [4] Uses:
 - (i) It is consumed as a protein rich food (65-70% protein).
 - (ii) Commercial production of β carotene.
- (iii) The phycocyanin pigment obtained from the plant body is used in cosmetic purposes.
- (iv) It is an useful antioxident because of the high mineral Fig. 8.23: Spirulina content.
 - (v) The γ linolenic acid is an essential fatty acid (present in mother's milk).
- (vi) The enzyme super oxide dismutase present in the plant body prevents aging in human.

8.8.2. FUNGI: Mushrooms.

(1) Introduction: The mushrooms include a group of higher fungi which belong to the division Eumycota and sub-division Basidiomycotina. This may include the various edible forms like the button mushroom as Agaricus bisporous; oyster mushroom or Pleurotus sajar-caju, paddy straw mushrooms or Volvariella volvacea and the milk white mushrooms or Calocybe indica. It may also include the deadly poisonous. Amanita phalloides or non-edible, non-poisonous forms like Coprinus, Inocybe. But considering the global acceptibility and palatability of the button mushroom Agaricus, it is discussed in the ongoing paragraphs.

[2] Systematic Position: (Webster, 1980)

Division: Eumycota

Sub-division: Basidiomycotina

Class: Hymenomycetes
Order: Agaricales
Family: Agaricaceae
Genus: Agaricus

Indian species: A. campestris, A. bisporus, A. bitorquis.

- [3] General Characters: The fungi is saprophytic, contains septate mycelia, the spore bearing structures are called basidiocarps, which are edible and bears the basidia and basidiospores. The basidiocrap consists of a stalk like stipe and umbrella like pileus and the lower surface of the pileus consists of gills.
- [4] Useful parts: The entire basidiocarp is edible, but they are usually collected for consumption at their early stage of development.
 - [5] Uses:
- (i) The sporocarp is consumed as a protein enriched vegetable diet.



Fig. 8.24: Agaricus basidiocarp.

- (ii) The percentage of protein is 4-5 %.
- (iii) The cholesterol content is low, so it is good for cardiac patients.
- (iv) As it grows on waste materials enriched in cellulose, it is an ideal way of recycling them.
 - (v) It can be an useful export item and can bring in foreign exchange.

8.8.3. BRYOPHYTE: Sphagnum.

[1] Systematic Position: (Parihar, 1960)

Division: Bryophyta

Class: Bryopsida

Order: Sphagnales

Family: Sphagnaceae
Genus: Sphagnum

Indian species: S. teres; S. ovatum.

[2] General Characters: The Sphagnum is a leafy bryophyte. The gametophytic plant body is differentiated into rhizoidal roots, non-woody reduced stem and leaves. The sporophyte is differentiated into foot, seta and capsule, it is dependent on the

gametophyte. It is a cosmopolitan moss, but grows well in swampy, semi-aquatic areas. It is also called **bog moss** or **turf moss** or **peat moss**.



Fig. 8.25: Sphagnum plant body.

- [3] Useful parts: The entire plant body is useful, even the dried plant body is used as peat fuel.
 - [4] Uses:
- [i] As an antiseptic material: Sphagnum has antiseptic properties and during First World War, it was extensively used as a substitute for cotton in dressing of wounds.
- [ii] As a packing material: Sphagnum rapidly absorbs water and has a high water-holding capacity and hence used as a packing material in the shipment of various living materials like seedlings, flowers, cuttings, bulbs etc. Because of its soft, spongy texture, it also acts as a mechanical buffer for fragile materials.
- [iii] As fuel and source of industrial material: As a result of its rapid growth and huge accumulation, Sphagnum shows slow decomposition in swamps and bogs and ultimately forms a compact, carbonised peat, commonly used as a fuel in different parts of Europe like in Scotland, Ireland, Wales. The peat also produces various industrial materials like paraffin, acetic acid, ammonia and tar.
- [iv] In reclamation of soil: Sphagnum induces ecosere and transforms an aquatic ecosystem into

peatland ecosystem and there by helping in the reclamation of soil. It also maintains the acidic pH of the soil, which is particularly useful for the growth of specific plant vegetation.

[v] In seed bed and as greenhouse material: Sphagnum is enriched in moisture and therefore it is used in preparing seedbed and also in the greenhouses as a rooting medium.

8.8.4. PTERIDOPHYTE: Marsilea.

[1] Systematic Position: (After Smith, 1953)

Division: Pteridophyta Class: Filicinae

Order: Marsileales

Family: Marsileaceae
Genus: Marsilea

Indian species: M. condenseta, M. quadrifolia.

[2] General Characters: Marsilea is an aquatic fern, it is a typical non-woody vascular plant with rhizomatous stem, quadrifoliate leaves, long petiole and the spore bearing structures are called sporocarp.

[3] Useful parts: The entire plant body along with the reproductive structure is useful.

[4] Economic importance: The various economic importances are as follows:

[i] As food: Leaves of Marsilea are commonly consumed as vegetable; sporocarps are eaten as food and the whole plant is also a good cattle food.

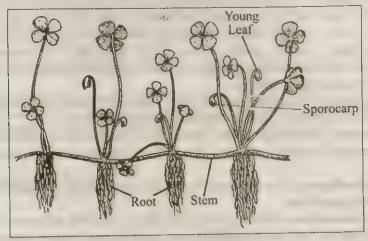


Fig. 8.26: The Marsilea plant with sporocarp.

[ii] As medicines: Different parts of Marsilea are useful as medicines, the plant extract is used in curing nerve-ailments. The leaf extracts are used as sedative and also to relieve muscular pains. The active principle Marsilin extracted from Marsilea is effective in treating cancer.

[iii] As a source of starch: Marsilea contains huge amount of starch and is used

in bakeries and other food industries as a potential source of starch.

8.8.5. GYMNOSPERM: Pinus.

[1] Systematic Position: (As per D. D. PANT, 1979)

Division: Coniferophyta

Class: Coniferopsida

Order: Coniferales

Family : Pinaceae Genus : Pinus

Indian species: P. roxburghii, P. armandi, P. gerardiana.

[2] General Characters: Pinus is a woody tree, typically excurrent in habit, the root is tap root system, profusely infested with vesicular arbuscular mycorrhizal fungi, the leaves are scaly or spiny in nature. The male cone is smaller, non-woody and borne in cluster containing the microsporangia. The female cone is woody, larger in size, bears the ovules. Fertilization is simple, polyembryony is common. There is no definite spore dispersal method observed.

[3] Useful parts: The secondary wood of the stem, the resin obtained from the stem, the cone, the ovule.

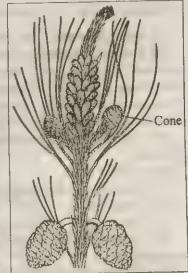


Fig. 8.27: The shoot of *Pinus* bearing male and female cones.

- [4] Uses: Most of the species of *Pinus* have economic importance and they are discussed below:
- [i] As timber: The wood of *Pinus palustries* is used in ship-building, making of the bodies of trucks and floor of wagon. The wood of *P. roxburghii*, *P. wallichiana and P. nigra* are used in making furnitures, packing cases, door-frames, match sticks.
- [ii] As resin: Various species of *Pinus*, viz. P. roxburghii, P. insularis are the potential sources of oleo-resin and terpentine, used in the manufacturing of paints and varnishes, lacquers and medicines.
- [iii] As amber: It is a fossil resin (B. 'pala') obtained from a fossil member called *Pinites succinifera* and is a precious material used in jewellery.
- [iv] As food: The seeds of many species like *P. gerardiana*, *P. edulis* are edible and commercially termed as chilgoza. The fatty oil extracted from *P. cembra* is also edible.
- [v] As medicines: The extracts of seeds of *P. roxburghii* is used against stomach disorders and gonorrhoea.
- [vi] As decoratives: Majority of *Pinus* species are grown as decorative plants, both in the garden as well as in the roadside areas, preventing soil erosion in the temperate condition.

8.8.6. ANGIOSPERMS

I. Monocotyledonae: Bamboo

[1] Systematic Position:

Class: Monocotyledonae
Order: Glumiflorae
(Series)

Family: Gramineae
Genus: Bambusa

Indian species: B. arundinacea.

[2] Floral formula: Br. $\oplus Q^{\dagger}P_{3}A_{6}G_{1}$

[3] General Characters: Arborescent perennial herb, stem cylindrical with solid node and hollow internode, leaves with very short petiole, leaf

blade triangular, flowers bisexual, bracteate, trimerous, perianth 3, stamens 6 in 2 whorls, carpel solitary, ovary superior, one chambered, single anatropous ovaule, stigma bifid, fruits caryopsis.

[4] Useful parts: The entire plant, the stem, leaves flowers are useful.

[5] Uses:

- (i) The ply bamboo is used for wall panelling, floor tiles, paper making etc.
 - (ii) It is used for reinforcing beams of buildings.
- (iii) It has a general aesthetic beauty, used for wind break and landscape design.

(iv) A common plant of agroforestry.

- (v) Used in the making of art works, handicrafts.
- (vi) Ancient historical records (12th century BC) are written on bamboo strips.



Fig. 8.28: Bamboo

plant.

- (vii) It may be used as a domestic fuel.
- (viii) A rural, building material also used in urban areas for painting, plastering buildings.
 - (ix) It is used in preventing soil erosion and protect the fragile river beds.
 - (x) Different musical instruments like flute are made out of it.
 - (xi) Used in chinese acupuncture and in ayurveda.
- (xii) Medicines for cough, asthma are prepared, root extract is used in kidney diseases.
 - (xiii) The pulvarized bamboo barks are used as an antioxidant.
 - (xiv) Bamboo extract is antibacterial in nature and may be used as food preservative.
 - (xv) Bamboo shoots are directly consumed in chinese preparations.

H. Dicotyledons: (a) Jute:

[1] Systematic Position:

Class : Dicotyledonae

Order : Malvales

Family : Tiliaceae

Genus : Corchorus

Indian species ! 'C. capsularis ; C. olitorius.

[2] Floral formula: $\bigoplus Q^{1} K_{s} C_{s} A_{10} \underline{G}_{(s)}$.

[3] General Characters: Jute is a fibre yielding semi-woody shrub, the fibres are obtained from the secondary phloem fibres of the stem, the plant may be 6-10 m in height, woody branches present, the leaves are lens shaped with serrated margin, the

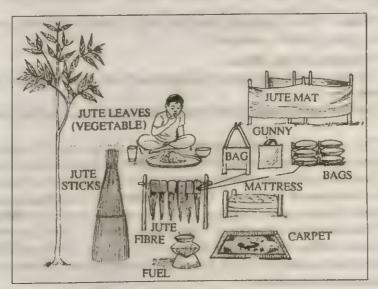


Fig. 8:29: Jute plant and its useful products.

flowers are bisexual, regular, pentamerous, ovary superior, fruits capsule and seeds exalbuminous. There are 2 major cultivated species of Jute, viz. Corchorus capsularis (Teeta pat or white jute) and Corchorus olitorius (Mitha pat or tassa pat).

[4] Characteristics of Jute fibre:

[i] They are elongated, sclerenchymatous fibres of secondary phloem.

[ii] Individual fibres are joined with each other, showing interlocking pattern and ultimately form a long, lignified fibre with bigger diameter.

[iii] The fibres are tough, stiff, lustrous and pale yellow to white in colour.

[iv] They have a silky appearance and may be 6-10 ft. long.

[v] The fibres are grouped in alternate, concentric rings.

[vi] The fibres are separated from the main stem by bacterial fermentation (Clostridium sp.), commonly termed as retting.

[vii] Each bundle represents one strand (reed) consisting of fifty fibre cells.

[5] Useful parts: Jute fibres, stem, leaves, seeds are economically useful.

[a] Fibres:

[i] Jute fibres are used in the manufacturing of bags, sacs, ropes, tarpaulins, oil cloths, twines, linoliums, canvases, gunny bags etc.

[ii] The superior quality fibres are also used in the preparation of paper boards, coarse-cloth, rugs, carpets, curtains and various upholstery products.

[b] Sticks:

- [i] After the extraction of fibres, the jute sticks and their broken ends or butts are used as fuel.
 - [ii] The sticks and butts are also used in the manufacturing of paper boards.
 - [iii] They may be used as a fencing material or thatching roofs.
 - [iv] They are used in garden as support to twiners and climbers.
- [c] Leaves: The leaves of Corchorus olitorius (mitha pat) is consumed as a vegetable.
- [d] Seeds: The oil extracted from the seeds is used in the manufacturing of varnishes, soaps, cosmetics, paints etc.

[6] Processing of jute fibres:

- [i] The fully-grown jute plant is harvested just before fruiting, during the period June-September.
- [ii] The harvested plants are left for sometime in the ground for the shedding of leaves.
- [iii] They are tied in bundles and immersed in a shallow part of stagnant waterbody for the fermentation activity of bacteria like Clostridium acetobutyricum.
- [iv] The fibres get lossened from the main-stem by the destruction of pectins, gums and other mucilaginous substances. The whole process of separation of jute fibres from the jute stick may take a total time of 5 weeks and it is termed as **retting**.
- [v] The post-retting extraction of fibres is done manually, when the terminal end of the sticks are broken with a hammer and separated as butts. The released fibres from the butts are tied to hand and given a 'to and fro' jerking in water, by which the fibres get separated from the jute stick.
- [vi] The extracted fibres are thoroughly washed in clean water and kept well spread out in the sun for about 2-3 days for drying.
- [vii] The dried fibres are tied into bundles or bales and sent to the market for sale or to the godowns for storage.

(b) Lemon:

[1] Systematic Position:

Class : Dicotyledonae Order : Geraniales Family : Rutaceae Genus : Citrus

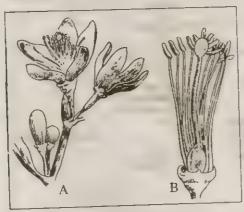


Fig. 8.30: Lernon flower.

C. medica, C. decumana. Indian species:

[2] Floral formula: $\bigoplus \vec{Q}^1 K_s C_s A_{s+s} \underline{G}_{(s)}$.

- [3] General Characters: Shruby habit, stem woody, leaves alternate, lamina gland-dotted, petiole winged, flower regular, pentamerous, stamens free, ovary superior, axile placentation, fruit hesperidium, seeds non-endospermic.
 - [4] Useful parts: Leaves and fruits.
 - Uses: [5]
 - (i) The leaves may be used for imparting flavour to food.
 - (ii) Lemon juice is consumed as a drink.
 - (iii) The fruit is the raw material for the preparation of industrial citric acid.
 - (iv) In the making of pickles.
 - (v) It can also used in cooking for imparting the sour taste.
 - (vi) It is used for curdening of milk.

8.9. Life Cycle

The life cycle of an organism shows the sequence of events taking place in the life of an organism. It can be broadly classified into two major phases, viz. the gametophytic phase or the haploid phase and the sparophytic phase or the diploid phase. In lower organisms like algae, fungi and bryophytes, the gametophytic phase is usually prevalent and it is called haplobiontic life cycle, in ferns the sporophyte and gametophyte are equally prevalent and it is called haplo-diplobiontic, while in gymnosperms and angiosperms, the diploid phase is prevalent and is called diplobiontic. This alternation between the haploid and diploid phase in the life cycle of an organism is known as alternation of generation.

8.9.1. TYPES OF LIFE CYCLE

As already stated that life cycles in plants can be of 3 major types.

[1] Haplobiontic Cycle: The predominant plant body is haploid in nature, it reproduces asexually or vegetatively to produce the haploid plant body again. Towards the end of the life cycle, they produce the gametes, which fuse with each other to



Fig. 8.31. Hapiobiontic life cycle of an unicellular algae Chlamydomonas produce the diploid zygote, that undergoes reduction division quickly and gives rise to the haploid plant body again e.g. Life cycle of Chlamydomonas or the fungi Mucor

[2] Haplo-diplobiontic Cycle: The organism shows both the haploid and diploid phases as quite predominant phases. Both the haploid and diploid plant bodies have

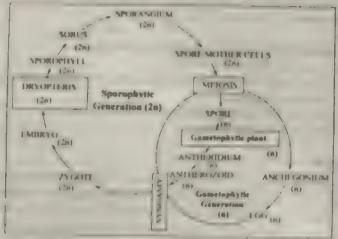


Fig. 8-32. Haplo diplobiontic life cycle of Decopteris

the ability to prepare their own food, so both can survive independently. They are observed in ferns and they exhibit distinct alternation of generation e.g. Desopteris

[3] Diplobiontic Cycle: The higher plants exhibit diplobiontic life cycle because the predominant plant body is the sporophyte, which produces the gametophytes, that

are short lived and always borne within the sporophyte. It is found in gymnosperms and angiosperms.

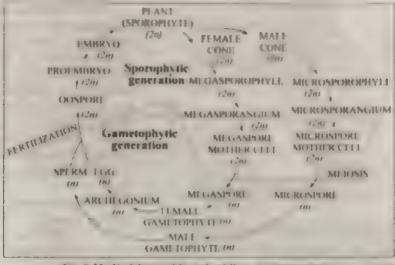


Fig. 8-33 Diplobiontic life cycle of Pinus (a gymnosperm)

8.9.2. LIFE CYCLE PATTERN IN YEAST

Yeast is a group of unicellular lungus that exhibit all 3 types of life cycle, viz., haploblontic, haplo-diploblontic and diploblontic. It was denoted by Guillermond, 1940.

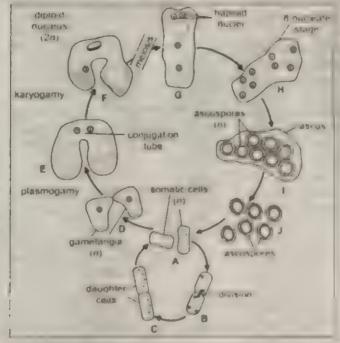


Fig. B.34. Haptobiontic life cycle of Schizosaccharomyces octospoeus. (A. I) (After Guillermond)

8.9.1. TYPES OF LIFE CYCLE

As already stated that life cycles in plants can be of 3 major types;

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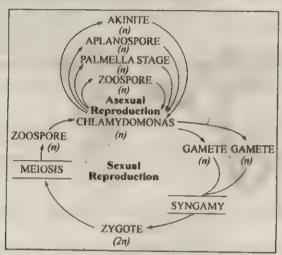


Fig. 8.31: Haplobiontic life cycle of an unicellular algae *Chlamydomonas*. produce the diploid zygote, that undergoes reduction division quickly and gives rise to the haploid plant body again e.g. Life cycle of *Chlamydomonas* or the fungi *Mucor*.

[2] Haplo-diplobiontic Cycle: The organism shows both the haploid and diploid phases as quite predominant phases. Both the haploid and diploid plant bodies have

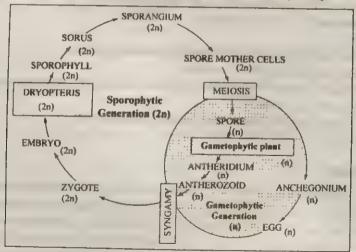


Fig. 8.32: Haplo-diplobiontic life cycle of Dryopteris.

the ability to prepare their own food, so both can survive independently. They are observed in ferns and they exhibit distinct alternation of generation e.g. Dryopteris.

[3] Diplobiontic Cycle: The higher plants exhibit diplobiontic life cycle because the predominant plant body is the sporophyte, which produces the gametophytes, that

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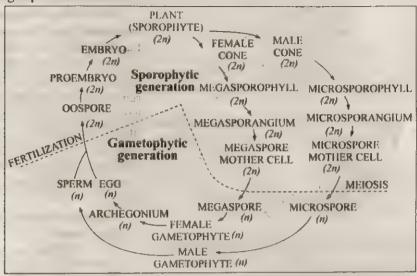


Fig. 8.33: Diplobiontic life cycle of *Pinus* (a gymnosperm).

8.9.2. LIFE CYCLE PATTERN IN YEAST

Yeast is a group of unicellular fungus that exhibit all 3 types of life cycle, viz., haplobiontic, haplo-diplobiontic and diplobiontic. It was denoted by Guillermond, 1940.

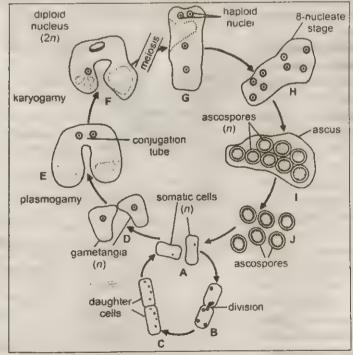


Fig. 8.34: Haplobiontic life cycle of Schizosaccharomyces octosporus. (A-J) (After Guillermond).

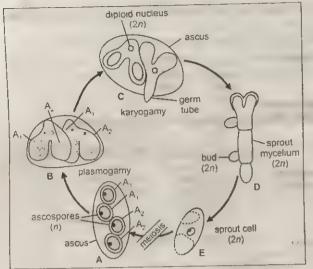


Fig. 8.35: Diplobiontic Life cycle in Saccharomycodes ludwigii.

ludwigii, the life cycle is diplobiontic in nature, where the diploid phase is predominant. The ascospores produced within a cell, fuse with each other to produce 2n cells, that germinate to produce a sprout mycelium and produce the diploid cells.

(c) Haplo-diplobiontic Life Cycle pattern in Yeast:

Saccharomyces cerevisiae, the life cycle is haplo-diplobiontic (as denoted by Guillermond 1940). The cells remain in both haploid and phases, which perpetuate by budding. The haploid cells undergo fusion to form the diploid zygote, which reproduces by budding, producing a number of diploid cells. Each diploid cell is converted to ascus and by meiosis, they produce 4-8 haploid ascospores. These ascospores after being liberated, undergo budding to produce a large number of haploid cells.

(a) Haplobiontic Life Cycle in Yeast:

In Schizosaccharomyces octosporus, the life cycle is haplobiontic, that is the life cycle is dominated by the haploid ascospores, which reproduce by budding. The haploid ascospores undergo fusion to produce the diploid zygote and immediately undergoes reduction division to produce the haploid cells again.

(b) Diplobiontic Life Cycle in Yeast:

In Saccharomycodes

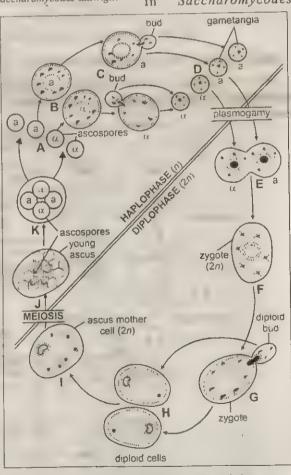


Fig. 8.36: Haplo-diplobiontic life cycle in Saccharomyces cerevisiae.

Lindegrens 1943, denoted the sexual mating strains of S. cerevisiae, where he showed that an ascus derived from 'A' zygote produces 4 ascospores, 2 belonging to 'A' strain and 2 to 'a' strain.

ALTERNATION OF GENERATIONS 8.9.3.

The term "alternation of generation" was introduced by Pichi Sermoli (1958) by studying the life cycle pattern of fern, where the diploid sporophyte and the haploid gametophyte are equally predominant and independent of each other. It can be classified in the following ways:

(a) Isomorphic alternation of generation: This process is so called because the sporophyte and gametophyte are morphologically similar and it is found in the life

cycle of the brown algae Ectocarpous siliculosus.

(b) Heteromorphic alternation of generation: This is most common form of alternation of generation found in majority of lower and higher plants. In this case, the sporophyte and gametophyte are distinctly different from each other. e.g., Dryopteris filix-mas.

(c) Triphasic alternation of generation: It is a special type of heteromorphic alternation of generation, where the sporophyte and gametophyte are different from each other, moreover the sporophyte shows more than one morphological forms. It is observed in the red algae Polysiphonia platycarpa. In this case, in addition to the gametophyte, the sporophyte are of two different types, which are the tetrasporophyte liberating the tetraspores and the carposporophyte liberating the carpospores.

8.10. Comparative Discussions

- Fungi and Bacteria:
- [a] Similarities:
- [1] The cell wall in both cases is devoid of cellulose and may contain muramic acid.
 - [2] They both may be parasitic or saprophytic in nature.
 - [3] They may reproduce vegetatively by binary fission.
 - [4] The asexual reproduction may be by the formation of endospore.
 - [5] The sexual reproduction may take place by conjugation.
 - [6] They have the ability to produce organic acid by fermentation.
 - [b] Dissimilarities:

[b] Dissimilarities:			
Points of Differences	Fungi	Bacteria	
Points of Differences		Saprophytic, parasitic, symbio-	
1. Nutrition	Saprophytic, parasitic or symbiotic in nature.	tic and autotrophic in nature.	
Vegetative body 2. Number of cell	They may be uni or multicellular.	They are always unicellular cells may remain in aggregated condition.	
3. Size	They are both microscopic and macroscopic in nature.	They are always microscopic in nature.	
4. Nature	and macroscopic in nature. They are always eukaryotic in nature.	They may be prokaryotic in nature.	

Points of Differences	Fungi	Bacteria
5. Cell wall	Cell wall contains muramic acid, mannan, glucan and chitin.	The cell wall contains peptidog- lycan components like n-acetyl muramic acid and n-acetyl glucosamine.
6. Nucleus	True eukaryotic nucleus present containing chromosomes.	The nucleus is represented by the nucleoid without nuclear membrane and containing single circular DNA.
7. Extra nuclear DNA	Usually absent.	Present in the form of plasmids and episomes.
8. Cell division / Reproduction	Amitosis, mitosis and meiosis.	By amitosis only.
9. Sexual organs	Male and female sex organs may be well developed.	Sex organs are not produced.
10. Gametes	Gametes are formed during sexual reproduction.	True gametes are not formed.
11. Sexual reproduction	By gametangial copulation, gametangial contact or by syngamy.	By conjugation, transformation, transduction and lysogeny.

(ii) Algae and Fungi:

- [a] Similarities:
- [1] Both have thalloid plant body and hence belong to the group thallophyta.
- [2] The sex organs are unicellular in nature.
- [3] The end product of sexual reproduction is the diploid zygote or zygospore, which undergoes reduction division to produce the haploid plant body.
 - [4] The embryo is not formed.
 - [5] The asexual reproduction occurs by the formation of zoospores.
- [6] The vegetative reproduction may occur in both the cases by the processes of fission and fragmentation.
 - [7] They both may participate in a symbiotic association.
 - [b] Dissimilarities:

Points of Differences	Algae	Fungi	
1. Habit and Habitat	Autophytic or symbiotic, may be terrestrial or aquatic.	Saprophytic, parasitic or symbiotic in nature, may be both terrestrial or aquatic.	
2. Nutrition	They are always autotrophic, rarely parasitic.	They are always heterotrophic in nature.	
Vegetative structure			
3. Celi wali	It is composed of cellulose, hemicellulose.	It is composed of glucan, mannan chitin etc,	
4. Pigments	Photosynthetic green pigment chlorophyll, carotenoids and phycobilins present.	Chlorophyll is absent, rarely contain pigments like neo-ercosporin.	
5. Stored food	Mainly starch.	Mainly glycogen.	

Points of Differences	Algae	Fungi
6. Tissue 7. Phases 8. Nature	Tissue development takes place. Haploid and diploid phases, no dikaryotic phase. Usually eukaryotic, blue-green algae is prokaryotic in nature.	Haploid, diploid and dikaryotic phases present. Always eukaryotic in nature.
9. Vegetative reproduction 10. Asexual reproduction	By fission, fragmentation. It is by zoospores, aplanospores, hyponospores.	By fission, fragmentation and budding. It is by chlamydospores, conidia, oidia, sporangiospores and other types.
11. Sex organ development 12. Female sex organ 13. Sexual reproduction	Simple to complex, from lower to higher groups. Oogonium. By plasmogamy, and diploidization. Important as a producer, food and	higher groups. Oogonium and ascogonium. By plasmogamy by dikaryon formation and diploidization.
14. Importance	production of drugs.	vitamins, protein and also causing diseases.

[iii] Dissimilarities between Algae, Fungi and Bacteria:

Points of Differences	Bacteria	Algae	Fungi
Nature Nutrition	Microscopic and unicellular. Autotrophic (with chlorophyll), and heterotrophic (both saprophytic and para-	Both microscopic and macroscopic, unicellular (Chlamydomonous), filamentous, Spirogyra to very large tree-like (kelps). Always autotrophic in nature, sometimes symbiotic with fungi, rarely parasitic.	Unicellular microscopic (yeast), mycelial in Mucor and very large fructification in Ganoderma. Always heterotrophic in nature, may be saprophytic, parasitic or symbiotic in nature.
3. Tissue	sitic in nature). No tissues are formed.	Parenchymatous tissue in multicellular forms.	Pseudoparenchyma, prosenchyma in multi- cellular forms.
Points of Differences	Bacteria	Algae	Fungi
4. Cell wall	It is formed of peptido- glycan, consisting of n-acetyl muramic acid and n-acetyl glucos-	Cell wall consists of cellulose.	Cell wall consists of glucan, mannan and chitin.
5. Nucleus	amine. It is prokaryotic in nature.	It is prokaryotic in blue green algae, eukaryotic in all other groups. Chromosome.	It is eukaryotic in nature. Chromosome.
6. Genetic	Single circular DNA.	Cinoniosonic	

Points of Differences	. Bacteria	Algae	Fungi
7 Cell division 8. Sex organs	Cell division by amitosis. Sex organs are not q formed.	It divides by mitosis and meiosis. Sex.organs like antheri- dium and oogonium are	It divides by amitosis, mitosis and meiosis. Sex organs develop.
9. Gametes	Gametes are not	formed. Gametes are formed.	Gametes are formed.
10. Sexual reproduction 11. Zygote	It is by conjugation, transformation and transduction. True zygote is not formed, the product is termed as partial zygote or merozygote.	It is by conjugation, syngamy, gametangial copulation and fertilization. The true (2n) zygote or zygospore is the product of sexual reproduction.	It is by conjugation, syngamy, gametangial contact and fertilization. The zygote or zygospore (2n) is the product of sexual reproduction.

[iv] Algae and Bryophyta:

[a] Similarities ! " "

[i] The plant bodies are not perfectly differentiated into root, stem and leaves in both the cases.

[11] The gametophytic generation is predominant.

[iii] The sporophytic generation is reduced and dependent on the gametophyte.

[iv] The gametophyte is chlorophyllous in nature.

[v] The sporophyte undergoes meiosis to produce the gametophytic plant body.

[vi] The gametophyte undergoes sexual reproduction to produce the zygote (2n), formed by sexual reproduction, develops into the sporophyte.

|b| Dissimilarities :

[D] Dissimulari	[D] Dissimilarities:			
Points of Differences	Algae	Bryophyta '		
1. Habitat	I. Mostly aquatic.	Mostly terrestrial or amphibious.		
2. Plant body	 Plant body may be unicellular, colonial, filamentous or some- times dendrobial. 	It is multicellular, sometimes thalloid or sometimes differentiated into basal rhizoidal and an aerial leafy portion.		
3. Rhizoids	3. Rhizoids are absent, may be replaced by holdfast.	3. Rhizoids present, can be of 2 types, smooth-walled and tuberculate.		
4. Chloroplast	4. The chloroplasts are of variable shapes, one or two in number.	4. Chloroplasts are discrete, discoid structures; many chloroplasts present in a cell.		
5. Pores	5. Pores favouring exchange of gases absent.	5. Pores at the tip of air chan- nels present.		
6. Asexual reproduction	It occurs mostly by the produc- tion of zoospores.	6. Gametophyte does not reproduce asexually; zoospores absent.		
7. Sexual reproduction	It occurs by isogamy, anisogamy, oogamy and also by conjugation.			

Points of Differences	Algae	Bryophyta
8. Female sex organ 9. Embryo 10. Life cycle	 8. It is single-celled and termed as oogonium. 9. Embryo is not formed. 10. It is mostly haploid, diploid phase is reduced. 	archegonium, 9. Embryo formation takes place 10. Haploid phase predominant, but diploid phase is compa-
11. Alternation of generation	11. The alternation of generation may be isomorphic or heteromorphic.	ratively more developed. 11. The alternation of generation is always heteromorphic

[v] Fungi and Bryophyta:

[a] Similarities:

[1] The plant body is thalloid in nature, not differentiated into root, stem and leaves.

[2] Majority of the species are terrestrial.

[3] The life cycle shows a predominant gametophytic generation and reduced sporophytic generation.

[4] The gametophyte reproduces sexually forming the 2n zygote, which marks the

beginning of the sporophytic generation.

[5] The diploid sporophyte undergoes reduction division to produce the haploid spores, which mark the beginning of the gametophytic generation.

ihl Discimilarities

[b] Dissimilari	[b] Dissimilarities:				
Points of Differences	Fungi	Bryophyta			
1. Plant body 2. Tissue	posed of hyphae and mycelium.	 It may be both thalloid or leafy in nature. The internal tissues are mostly parenchymatous and the vas- cular tissues are in the early stages of development. 			
3. Cell wall	3. The cell wall consists of man- nan, chitin etc.	 The cell wall is mainly cellulosic in nature. Present. 			
4. Chlorophyll 5. Reserve food	Absent. Mostly glycogen and volutin bodies.	Starch is the principle reserve food.			
6. Nutrition 7. Dikaryon	6. Saprophytic, parasitic or symbiotic in nature. 7. Dikaryotic stage (n+n) may be	6. Autotrophic in nature.7. Dikaryotic phase is absent.			
8. Asexual reproduction	8. It occurs by the production of different asexual spores, like oidia, conidia, sporangio-	8 Gametophyte does not reproduce asexually, but the sporophyte liberates asexual spores.			
9. Spore bearing structure 10. Sex Organ 11. Sexuality	spores, chlamydospores etc. 9. Spores are borne in specialised structures called sporocarps. 10. They are unicellular. 11. The sexuality is reduced.	 9. Spores are borne within the spore sac of capsule. 10 They are multicellular. 11. Elaboration of sexuality is observed. 			
12. Life cycle	12. The life cycle may be haplobion- tic, diplobiontic or haplo-diplo- biontic in nature.	12. The life cycle is haplo-diple biontic in nature with a prodominant haploid phase.			

[vi] Bryophyta and Pteridophyta:

- [a] Similarities:
- [1] The sex organs are multicellular in both the groups.
- [2] They exhibit heteromorphic alternation of generation.
- [3] The sporophyte exhibits asexual reproduction, while the gametophyte exhibits sexual reproduction.
 - [4] The antherozoids exhibit chemotactic movement towards the archegonial neck.
 - [5] The fertilization occurs with the help of water.
- [6] The gametophytes in both the cases originate with the formation of haploid spores.
 - [7] The spores originate from the reduction division of the (2n) spore mother cells.
 - [8] The gametophyte in both the cases are chlorophyllous in nature.

[b] Dissimilarities:

Points of Differences	Bryophyta	Pteridophyta
1. Plant body	1. The plant body is a gameto-	1. The plant body is a sporo-
	phyte.	phyte.
2. Nature	2. The sporophyte is dependent	2. The sporophyte and game-
	on the gametophyte.	tophyte are independent of
1 Dents	2 Character 1 1 1 1 1 1 1	each other.
3. Roots	3. The roots and rhizoids are	3. The sporophyte contains
4. Differentiation	absent in the sporophyte.	rhizoid like roots.
4. Differentiation	4. The sporophyte is differen-	4. The sporophyte is differen-
	tiated into foot, seta and cap-	tiated into root, stem and leaves.
5. Vascular tissue	5. The differentiation of true	
54 Vasculai (issue	vascular tissue is lacking.	5. Vascular tissues are well differentiated.
6. Antherozoids	6. Antherozoids are biflagellate.	6. Antherozoids are multifla-
o, Antherozolas	o. Antiferozoids are biffagellate.	gellate.
7. Archegonium	7. Archegonium is longer with	7. Archegonium is shorter,
,	5-7 neck canal cell and one	with one bi-nucleate neck
	ventral canal cell.	canal cell and one ventral
		canal cell.
8. Chemotaxism of	8. The chemotaxism exhibited by	8. The chemotaxism of anthe-
antherozoids	antherozoids is induced by	rozoids is induced by malic
	sucrose.	acid.

[vii] Pteridophyte and Gymnosperms:

[a] Similarities:

- [1] The sporophytic plant body is differentiated into root, stem and leaves.
- [2] The sporophytic phase is prevalent and independent in the life cycle.
- [3] The true vascular strands in the form of xylem and phloem present.
- [4] Xylem lacks trachea or vessels, while phloem lacks companion cells.
- [5] The leaves are dimorphic in nature i.e., scaly leaves and broader leaves (in some members).
 - [6] Presence of flask-shaped archegonia in the female gametophyte.

- [7] The embryo develops from the diploid zygote, which ultimately develops into the diploid sporophyte.
- [8] Like gymnosperm, some pteridophyte members can show the development of strobilus or cone-like structures.

[b] Dissimilarities:

Points of Differences		Pteridophyte		Gymnosperms
1. Life cycle	1.	The life cycle shows independent existence of gametophytic and sporophytic generation.	1;	The gametophyte remains within the sporophyte and is dependent on it for nourishment.
2. Size	2.	The sporophyte is small.	2:	The sporophyte is large and massive.
3. Secondary growth	3.	The cambium is absent, so there is no secondary growth.	3,	Cambium present, so massive secondary growth is observed.
4. Mycorrhiza	4.	The root is devoid of mycorrhizal association.	4,	There may be mycombizal association present in the roots.
5. Leaves	5.	Megaphyllous leaves, usually compound in nature.	5.	Megaphyllous leaves, may not always be compound.
6. Leaf anatomy	6.	The mesophyll is not well dif- ferentiated into palisade and spongy parenchyma.	6.	The mesophyll is well differentiated into palisade and spongy parenchyma.
7. Pollination	7.	The process of pollination is not required.	7.	The pollination process occurs with the help of wind
8. Fertilization	8.	Fertilization occurs in presence of water.	8.	Fertilization occurs in absence of water.
9. Pollen tube	9.	Pollen tubes are not formed, antherozoids directly enter the archegonia.		Formation of pollen tube is observed.
10. Nature of the	10.	They may be homosporous or	10.	They are always heteros-
spores		heterosporous in nature.		porous.
11. Protonema	11.	Protonema is formed before gametophyte formation.		Protonema is not formed.
12. Seed formation	12.	It is lacking.	12.	It always takes place.

[viii] Gymnosperm and Angiosperm:

[a] Similarities:

- [1] The sporophytic plant body is predominant, independent and differentiated into true root, stem and leaves.
 - [2] The gametophytic plants are reduced and is dependent on the sporophyte.
 - [3] The megaspore is retained within the ovule, even after fertilization.
 - [4] The male and the female gametes are distinctly different.
 - [5] The pollen grain shows prothalial cell, tube cell and generative cell.
 - [6] The pollen tube is well developed, that carries the non-flagellated male gametes.
 - [7] Matured stem contains secondary xylem and phloem.
 - [8] Stele consist of multiple leaf traces and leaf gaps.
 - [9] Zygote develops into the embryo within the seed.
 - [10] The embryo remains dormant for a specific time-period within the seed.

- [11] The developing embryo derives its nourishment from the nutritive endosperm tissue.
 - [12] The seed coat is differentiated into 2 layers, viz., testa and tegmen.
 - [13] Seed germinates to produce radicle and plumule.

[b] Dissimilarities:

Points of Differences	Gymnosperms	Angiosperms
1. Fruit formation	1. The fruits are not formed, the seeds remain exposed (naked seeded).	
2. Reproductive structures	2. The cones are formed, which are unisexual, i.e., male and female cones are different.	Cones are not formed, flowers may be unisexual or bisexual.
3. Perianth	3. They are not present.	3. They are present, which cover the essential whorls.
4. Male sex organ	 It is represented by microspores. 	ium and stamens.
5. Female sex organ	5. It is represented by megas- pore with archegonia.	5. The gynoecium is present, but archegonia is absent.
6. Ovary	6. The ovule is present, but over is not formed.	stigma present.
7. Endosperm	 The endosperm is haploid in nature and formed before fertilization. 	7. The endosperm is triploid (3n) in nature and it is formed after fertilization.
8. Fertilization	8. Double fertilization is absen	
9. Polyembryony	Presence of cleavage or adventitive polyembryony.	9. Polyembryony is absent.
10. Development of zygote	cai division.	absent.
11. Seed dispersal	11. There is no method of seed dispersal present. (**1) 240 44	11. Method of seed dispersal
12. Cotyledons	12. Number of cotyledons may more than two.	

8.11. Matters to recollect

- Taxonomy is a science describing the principles of classification.
- Taxonomy comprises of identification, nomenclature and classification.
- Classification follows taxonomic hierarchy.
- Identification is carried out with the help of specially designed literatures or keys.
- Keys can be indented or bracketed in nature.
- Nomenclature involves scientific naming of plants.
- Binomial nomenclature includes the generic and specific epithet.
- Binomial nomenclature was proposed for the first time in 1753 in Systema Naturie (10th Edition).
- The species are the lowest major unit of classification.
- Sub-species are sometimes added to scientific name, giving rise to trinomial nomenclature.

- Taxon is a general name denoting unit of classification.
- ICBN denotes the International Code of Botanical Nomenclature.
- It is formulated for the first time in Paris in 1867.
- ICBN proposed the use of Latin for naming of plants and animals.
- The introduction of typification, Latin diagnosis, author citation, priority are some of the major aspects of ICBN.
- Classification means sequencial arrangement of plants and animals.
- Classification can be artificial, natural and phylogenetic in nature.
- Linnaeus proposed artificial classification, which was based on superficial characteristics.
- Bentham and Hooker proposed the natural system of classification in which the morphological characters were considered in details.
- Engler and Prantl, Hutchinson proposed the phylogenetic system of classification which gave more stress on evolutionary tendancy or cladistics of an organism.
- In the recent years there have been a gradual shift from classical or alpha taxonomy to experimental or omega taxonomy.
- Viruses are intermediate between living and non-living, in recent years they have been considered as acellular prokaryots.
- Viruses can be classified on the basis of their shape and the type of nucleic acid.
- Bacteria are prokaryots, classified on the basis of their shape, cell wall and nutrition.
- Rickettsia, Actinomycetes, Chlamydia and Mycoplasma are organisms very close to bacteria, placed along with bacteria under prokaryots.
- Algae can be classified mainly on the basis of the pigment present in them, like blue green, green, yellow green, brown, red etc.
- Fungi can be classified into four major types like phycomycetes, ascomycetes, basidiomycetes and deuteromycetes.
- Bryophytes can be divided into 3 major groups called Hepaticae, Anthocerotae and Musci.
- Pteridophytes are classified as Psilotopsida, Lycopsida, Sphenopsida and Pteropsida.
- Gymnosperms can be classified as Cycadopsida, Coniferopsida, Ginkgopsida, Gnetopsida.
- Angiosperms are broadly classified into monocots and dicots.
- Viruses contain only DNA or RNA and only replicate within specific host.
- Bacteria has nucleoid, 70S ribosomes, extranuclear DNA, simple flagella.
- Algae have a cellulosic cell wall, different types of chloroplast and chlorophyll pigments, contains storage starch.
- Fungi are non chlorophyllous organisms with chitin in their cell wall, survives as saprophyte or parasite.
- Bryophytes are amphibious plant, with predominant gametophyte, thalloid or leafy in nature. The ofference of the problem of th
- Pteridophytes are the true vascular plants with independent sporophyte and gametophyte showing distinct heteromorphic alternation of generation.

- Gymnosperms are naked seeded plant with massive secondary wood and reproductive structures borne in cones.
- Angiosperms or flowering plants produce the seeds within the fruits, representing the highest evolved plants.
- Spirulina is a blue green algae rich in proteins, vitamins and antioxidants.
- Mushrooms are group of higher fungi, mostly edible in nature with high percentage of protein.
- Sphagnum or bog moss is a natural bandaging material, has the ability to change an ecosystem.
- Marsilea is an edible aquatic pteridophyte.
- Pinus produces timber, turpentine and also used as a decorative plant.
- Bamboo is a monocot plant with woody stem used mostly as a construction material and preventing soil erosion.
- Jute is a dicot plant producing the jute fibres of commercial importance.
- Lemon is also a dicot plant useful for the commercial production of citric acid.
- The life cycle of a plant can be haplobiontic (in thallophytes), haplo-diplobiontic (in pteridophytes) and diplobiontic (in spermatophytes).
- Yeast is a group of unicellular fungi with the capability of exhibiting all the 3 types of life cycles.
- Every organism shows an alternation of generation between the haploid or gametophytic phase and diploid or sporophytic phase.
- The alternation of generation is usually heteromorphic in nature, sometimes it may be isomorphic or triphasic in nature.

8.12. Summary

Taxonomy deals with the principles of classification, it includes 3 major components, viz., identification, nomenclature and classification. Classification follows the taxonomic hierarchy. Identification is done with the help of specially designed literatures called keys, which can be indented or bracketed in nature. The nomenclature is based on the book Systema Naturie (10th Ed.) written by Linnaeus in 1753 and Species Plantarum in 1758. It is binomial in nature, having the generic and specific epithet, though later names of sub-species or tribes were also included. But each of them is considered as a taxon or unit of taxonomy. The International Code of Botanical Nomenclature deals with the principles of taxonomy. The first code was at Paris in 1867 and the last one was at Geneva in 2005. Some of the major aspects of taxonomic codes are typification, Latin diagnosis, author citation, law of priority etc. Classification is sequential arrangement of plants & animals. There are three types of classification systems viz. Artificial system, Natural system and Phylogenetic system. Artificial system was too superficial proposed by Linnaeus. Natural system was based on in-depth morphological considerations, proposed by Bentham and Hooker and practised in different botanic gardens. Phylogenetic system is a comparatively recent development by Hutchinson, Englar and Prantl and it considered the phylogenetic or cladistic relationships between different organisms.

Vertical classification includes relationship between living organisms and their ancestors. Horizontal classification includes comparison between two living organisms. Present day taxonomy has the incorporation of data from cytology, palynology and the classical taxonomy has been largely replaced by experimental taxonomy.

Viruses are intermediate between living and non-living, they are classified on the basis of nucleic acid and shape. Bacteria are prokaryotic organisms classified on the basis of shape, cell wall and nutrition. Algae are classified on the basis of pigment present. Fungi are divided into four major groups on the basis of mycelia and spore forms. Bryophytes are classified on the basis of thallus structure into Hepaticae, Anthocerotae and Musci. Pteridophytes are classified as Psilotopsida, Lycopsida, Sphenopsida and Pteropsida. Gymnosperms are classified as Cycadopsida, Coniferopsida, Ginkopsida and Gnetopsida. Angiosperms or flowering plants are classified into monocotyledonous and dicotyledonous plants.

Viruses consist of nucleic acid and protein, replicating only within specific host, but outside the hosts body, they behave as inanimate particles. Bacteria have a cell wall formed of peptidoglycan, they are devoid of membrane bound organelle, contains simple flagella, 70S ribosome and a primitive nucleus called nucleoid. Algae is a photosynthetic organism having cellulosic wall, different types of pigment and stored food as storage starch. Fungi are non-chlorophyllous organism having chitin in the cell wall, survive as sporophyte and reproduce by asexual spore forms. Bryophytes are amphibious plants, which may be thalloid or leafy in nature having predominant gametophyte and dependent sporophyte. Pteridophytes are land vascular plants with proper stele having independent sporophyte and gametophyte, showing distinct alternation of generation. Gymnosperms include big trees with naked seeds usually borne in cones. Angiosperms are flowering plants with seeds borne within fruits, exhibit double fertilization and are considered to be the highest evolved plants.

Spirulina are filamentous blue green algae with high amount of protein, vitamin, minerals and antioxidants. Mushrooms are protein enriched higher fungi which may be edible in nature and serve as a potent source of vegetable protein. Sphagnum or bog moss is important as a packaging or bandage material important as pit fuel. Marsilea are edible aquatic fern, bearing the spores within specialized structures called sporocarps. The Pinus are important for producing timber, turpentine and also used as a decorative plant. Bamboo are monocot plants where the stem is used mainly for constructional purpose and prevents soil erosion. Jute is a dicot plant which may be edible and produces economically important secondary phloem fibres. Lemon plant produces juicy fruits, which produces citric acid of commercial importance.

The life cycle includes the various events occurring in a particular organism. In lower organism, like thallophytes, the life cycle is haplobiontic, it is haplo-diplobiontic in bryophytes and pteridophytes and is diplobiontic in spermatophytes like gymnosperms and angiosperms. Yeast is a group of unicellular fungi exhibiting all the three types of life cycle. When the sporophyte and gametophyte are identical to each other, the alternation is isomorphic in nature, which is observed in a brown algae *Ectocarpus*, in majority of the cases, it is heteromorphic in nature and in some cases like in the red algae *Polysiphonia*, it is triphasic in nature.

8.13. Naming/Discovery/Discoverer

[1] Aristotle (384-322 B.C.) divided animals into Anaima (without blood) and Enaima (with blood).

[2] Theophrastus (371-287 B.C.) divided plants into herbs, undershrubs, shrubs

and trees.

[3] Caspar Bauhin (1596) first proposed the naming of plants by two names.

[4] John Ray (1627-1705) divided plants into Herbae and Arborea.

- [5] Carrolus Linnaeus (1707-1778) gave the first classification of plants in 1758 and animals in 1753 and known as father of taxonomy.
- [6] Lamarck (1774-1829) gave the animal classification.

[7] De Candolle (1813) proposed the term taxonomy.

[8] G. Bentham and J. D. Hooker (1862-1883) gave the natural system of classification of plants in 3 volumes of Genera Plantarum.

- [9] Adolf Engler and Karl Prantl (1886-1892) gave the first model of phylogenetic system of plant classification in 20 volumes of "Die Natürlichen Pflanzen Familien".
- [10] John Hutchinson (1926) gave the modern form of phylogenetic classification and revised it in 1950 in 3 volumes of "The families of flowering plants".
- [11] Gwnne Vaughan and Barnes (1937) gave a well documented classification of fungliances of a absorber land and process of a result of the control of the c
- [12] Fritsch (1945) gave the most comprehensive classification of algae.

[13] Smith (1955) forwarded the classification of pteridophytes.

- [14] Pichi-Sermolli (1958) denoted the phenomenon of alternation of generation in ferms [17] 2000 M 2 2000 M 2
- [15] Parihar (1960) proposed the well accepted classification of bryophytes.

[16] Henning (1966) proposed the modern concept of biosystematics.

- [17] Mentzer (1966) introduced the branch of chemotaxonomy and is known as the father of chemotaxonomy.
- [18] A. Lwoff (1966) classified viruses on the basis of their nucleic acid content.
- [19] Takhtajan (1967) proposed the modern phylogenetic classification based on genetics, embryology and biochemistry.
- [20] Sneath and Sokal (1923) proposed the modern form of numerical taxonomy.
- [21] Stabbins (1974) denoted the importance of cytology and genetics in taxonomy.

[22] Webster (1980) gave the modern classification of fungi.

[23] Williams and Shaw (1989) proposed the modern comprehensive classification of bacteria.

8.14. Answers to Special Questions

(1) What is systematics?

Ans. Study of diversity of living organisms and their inter-relationship.

[2] What is classification? The paper of the behave stories.

Ans. The process of arranging the organisms depending upon their similarities.

[3] What is taxonomy?

Ans. Taxonomy includes the principles, procedures and rules of classification.

[4] What are keys?

Ans. They are systematic framework representing the diagonostic features of an organism helping in its identification.

[5] Why is Latin used in scientific names?

Ans. It is not the official language of any country. What is trinomial nomenclature?

[6] Ans. When the name of the sub-species is also included along with the genus and species e.g. Homo sapiens.

What is sibling species? 171

Ans. When two morphologically similar species differ physiologically e.g. Some female Anopheles mosquitoes carry malarial parasites.

What are sympatric species? [8]

Ans. When two dissimilar species occupy the same habitat. e.g. Ascaris and Amoeba remain in human intestine.

[9] What are allopatric species?

Ans. When two similar species occupy different geographical area. e.g. African and Indian Lion.

What are taxon? [10]

Ans. It is a taxonomic unit, used in hierarchic classification.

Which virus has binal structure? [11]

Ans. Bacteriophage shows binal structure with a geometrical head and helical

Name a prokaryot smaller than bacteria. [12]

Ans. Mycoplasma.

Which group of bacteria are mostly responsible for antibiotic production? [13] Ans. Soil borne bacteria or actinomycetes.

What are the common name bacillariophyceae and xanthophyceae? [14] Ans. Diatoms and yellow green algae.

Which group of algae has unicellular diploid cells? [15]

Ans. Bacillariophyceae. Which spores have larger size than the vegetative cells? [16]

Ans. Auxospores. Which group of fungi not exhibit perfect stage? 17

Ans. Fungi Imperfecti or Deuteromycotina. What are holocarpic and eucarpic fungi? [18]

Ans. The fungus where the entire vegetative cell forms the reproductive cell is holocarpic fungi e.g. yeast. But the fungus where a part of the mycelia forms the reproductive structure is called eucarpic fungi e.g. Penicillium.

What is chitin? [19]

Ans. It is a nitrogenous polysaccharide present in the cell wall of fungi and also in the body of insects.

Why fungi require magnesium though it is devoid of chlorophyll? [20] Ans. Magnesium acts as a cofactor for various enzymes and also helps in the binding of the ribosomal subunits.

[21] What is a dikaryon?

Ans. The cells of a filamentous basidiomycetous fungi contain a pair of nucleii

called dikaryon which represents the intermediate stage between the haploid and diploid stages.

[22] What are sporocarps?

Ans. The spore bearing structures of higher fungi belonging to class ascomycetes and basidiomycetes are called sporocarp, which are of two types, viz., ascocarp and basidiocarp.

[23] Which group of bryophytes are in between the thalloid and leafy bryophytes?

Ans. Anthocerotae-e.g. Anthoceros.

[24] What are nurse cells?

Ans. They are sterile spore mother cells, which provide nourishment to the spores within the capsule of *Riccia* thallus.

[25] What are columella?

Ans. The central sterile strand within the capsule of moss, which helps in spore dispersal is known as columella.

[26] What is the other name for vascular cryptogams?

Ans. Pteridophytes.

[27] Name a plant where incipient heterospory is found.

Ans. Equisetum arwense.

[28] Name the spore bearing structures of pteridophytes.

Ans. The sporangia is the spore bearing structure borne within sorus or within the strobilus.

[29] Name the gymnosperms where cones are absent.

Ans. The Cycas and Ginkgo do not have female cone but in case of Gnetum, both male and female cones are absent.

[30] What are the angiospermic features of Gnetum?

Ans. (i) Presence of xylem vessels.

- (ii) Presence of companion cells in phloem.
- (iii) Presence of perianth within the cupule.

(iv) Presence of broad lamina.

[31] What are the two major nutrients present in Spirulina?

Ans. It consists of mineral nutrients, vitamins and act as an antioxidant.

[32] Name two edible mushrooms grown in tropical country.

Ans. Volvariella volvacea; Pleurotus sajor-caju.

[33] Name two edible mushrooms grown in temperate climate.

Ans. Agaricus bisporus; A. campestris.

[34] Name a species of button mushroom developed in India.

Ans. Agaricus bitorquis.

[35] What is the scientific name of milk white mushroom? Ans. Calocybe indica.

[36] How is Sphagnum useful as a fuel?

Ans. Dried Sphagnum plant body produces peat, which is useful as a fuel.

[37] How is *Pinus* useful for paint industry?

Ans. *Pinus* stem contains oleo-resin, which is also called turpentine and is useful as an organic solvent.

[38] How is bamboo useful as a food?

Ans. The young bamboo shoot is considered as a delicacy in China and other countries.

[39] How is citric acid obtained commercially?

Ans. Citric acid is obtained from the fruit of lemon.

What is isomorphic alternation of generation?

Ans. The alternation of generation where the sporophyte and gametophyte look like each other is called isomorphic alternation of generation. e.g. Brown algae Ectocarpus.

Name the 3 phases in the life cycle of the red algae *Polysiphonia*.

Ans. Carposporophyte, tetrasporophyte and gametophyte.

A. Essay type or Long answer type:

A. E	Issay type or Long answer type :	2 W-ite
	2 What do you understand by	taxonomy ? Write
[1]	beingly about the principles and pasts of classification.	i. 8.3.1 ; 8.2 ; 8.4)
		(Ans. 8.3.3)
[2]	Write briefly about the rules and codes of classification. Define taxonomy. Write in brief the principles and methods of classification.	Ans. 8.1.1; 8.3.3)
[3]	Define taxonomy. Write in brief the principles and methods of classification? What are its different types? Briefly discuss the basis	of classification.
[4]		(Ans. 8.4)
	What is taxonomy? Enumerate the international rules of nomenclature. (Ans. 8.1.1; 8.3.3)
[5]	What is taxonomy? Enumerate the international rules of indifferences? What do you mean by identification, nomenclature and classification? (A	What is the unit of
[6]	What do you mean by identification, nonconstant	ns. 8.1; 8.2; 8.4)
	classification and what is its significance?	lature.
[7]	classification and what is its significance? State the importance of taxonomy in biology and discuss the role of nomence [J.E.E. 1995]	(Ans. 8.1.1; 8.3.1)
	What is binomial nomenclature? Distinguish between term taxonomy, system	natics, classification
[8]	What is binomial nomenclature? Distinguish between term tandard	(Ans. 8.3.1; 8.1)
	and identification.	(Ans. 8.4)
191	what do you know about the Linnaean system of classification? What do you know about the Linnaean system of classification?	ent types of key.
[10]	What do you know about the Linnaean system of classification? What is taxonomic key? How it varies from hierarchy? Describe the difference of the control of	(Ans. 8.2.3)
12.01		(Ans. 8.6.1)
[11]	Give the outlines of viral classification.	(Ans. 8.6.2)
1121	Give the classification of bacteria showing an tite major groups	(Ans. 8.6.3)
[13]	Desire the outline of natural classification.	(Ans. 8.6.4)
[14]		(Ans. 8.6.6)
[15]	11-ware presidentities classified?	(Ans. 8.7)
[16]	Constitution of virus and pacteria.	(Ans. 8.7)
		(Ans. 8.7)
[17]		(Ans. 8.8.1)
[18]	characters and economic important	(Ans. 8.8.2)
[19]		(Ans. 8.8.3)
[20]		(Ans. 8.8.5)
21	. 1 and economic unpolitation -	(Ans. 8.8.6)
[22		
[23]		(Ans. 8.8.6)
[24	What is the floral formula of jute? State its economic importance State the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon. What are its economic importance state the systematic position of lemon is a typical life cycle of a plant?	? (Ans. 8.8.6)
[25	State the systematic position of lemon. What are its economic importance What are the different phases observed in a typical life cycle of a plant?	Describe the life cycle
{26	What are the different phases observed in a 57	(Ans. 8.9; 8.9.2)
	pattern in yeast.	
• B	Short Answer type: What is binomial nomenclature? Give the scientific names of a plant and an a	nimal.(Ans. 8.3.1; 8.3)
- [1	What is binomial nomenclature? Give the scientific hands of a plant and a what is its significance?	(Ans. 8.3.1; 8.3.5)
1.79	1 Who first introduced binomial nomenciature : What	(Ans. 8.3.1)
13	Who is the father of binomial nomenciature:	(Ans. 8.3.1)
1.4	Who proposed the term taxonomy	(Ans. 8.3.4)
15	What is trinomial nomenclature ?	

356	A TEXT BOOK OF BIOLOGI	
[6]	What is taxonomy? What are its aims?	(Ans. 8,1,1)
[7]	Discuss the rules of binomial nomenclature.	(Ans. 8.3.3)
[8]	What are the modern approaches to taxonomy?	(Ans. 8.5)
191		(Ans. 8.3.1)
[10]		(Ans. 8.6.1)
[11]		(Ans. 8.6.2)
[12]		(Aris. 8.6.4)
[13]		(Ans. 8.6.5)
[14]		(Ans. 8.6.7)
[15]		(Ans. 8.7)
[16]		(Ans. 8.7)
[17]	Name the most powerful protein food source of the world. How they are identifi	
[18]	the state of the s	(Ans. 8.8.2)
[19]		(Ans. 8.8.4)
[20]		(Ans. 8.8.5)
[21]	How is jute useful to us ? State its nature.	(Ans. 8.8.6)
	What is alternation of generation? State its different types.	(Ans. 8.9.3)
• €.		
		44 004
[1]	Who proposed Hierarchic classification?	(Ans. 8.2.1)
[2]	How binomials are constituted ?	(Ans. 8,3.1)
[3]	What is taxon?	(Ans. 8.2.1)
	What is species?	(Ans. 8.4.1)
[5]	How genus is written?	(Ans. 8.4.1)
		(Ans. 8.3.4)
[7]	Name a RNA and DNA virus.	(Ans. 8.6.1)
[8]		(Ans. 8.6.2)
[9]	What are diatoms ?	(Ans. 8.6.3)
- '	'What are phycomycetes ?	(Ans. 8.6.4)
	What are liverworts?	(Ans. 8.6.5)
[12]	What are lycopods?	(Ans. 8,6.6)
1131	State two features of gram positive bacteria.	(Ans. 8.7)
[14]	How fungi varies from algae other than not having chlorophyll?	(Ans8.7)
[15]	What are vascular cryptogams? Why they are so called?	(Ans. 8.7)
[1.6]	State two important features of gymnosperms.	(Ans. 8.7)
1174	Give the systematic position of Spirulina.	(Ans. 8.8.1)
[18]		(Ans. 8.8.2)
	What are the uses of bog moss ?	(Ans. 8.8.3)
[20]		(Ans. 8.8.6)
	Give the scientific names of misti pat and teeta pat.	(Ans. 8.8.6)
[22]	Who denoted alternation of generation?	(Ans. 8.9.7)
[23]	State an example of isomorphic alternation of generation.	(Ans. 8,9.3)
[24]	Name the yeast species showing haplobiontic, diplobiontic and haplo-diplobiontic alternative	
(3.6)	Give binomial name of a plant.	(Ans. 8.9.3)
		(Ans. 8.3.5)
[26]	Give a binomial name of an animal.	(Ans. 8.3.5)
[27]	Name the text of Bentham and Hooker.	(Ans. 8.4)
[28]	Name the text of Engler and Prantl.	(Ans. 8.4)
[29]	Who proposed the latest phylogenetic classification?	(Ans. 8:4)
[30]	What is basionym?	(Ans. 8.3.3)
[31]	What is trinomial nomenclature?	(Ans., 8.3.4)
[32]	What is Paris code?	(Ans. 8.3.2)
[33]	What is typification?	(Ans. 8.3.3)
[34]	What is meant by double citation ?	(Ans. 8.3.3)

		(4 9.2.0)
[35]	What is meant by law of priority ?	(Ans. 8.3.0)
[36]	What is Omega taxonomy?	(Ans. 8.9.1)
[37]	Name the predominant phase in the life cycle of thalfophytes.	(741131 01211)
[38]	How a sporophyte of pteridophyte reproduces?	(Ans. 8.9.1)
[39]	How does a gametophyte of pteridophyte reproduce ?	(Ans. 8.9.1)
[40]	Which group of plants show a well defined alternation of generation?	(Ans. 8.9.1)
• D.	Distinguish between: , ; annald out and	HH 0.4
[1]	Binomial and Trinomial nomenclature.	(Ans. 8.3.4)
[2]	Genus and Species. ""	(Ans. 8,4.1)
[3]	Natural and Phylogenetic classification.	(Ans. 8.4)
[4]	Taxonomy and Systematics.	(Ans. 8.1)
[5]	Taxonomy and Classification.	(Ans. 8.4.1)
[6]	Alpha taxonomy and Omega taxonomy.	(Ans. 8.1)
[7]	Species and Sub-species.	(WII250-4-1)
[8]	Allopatric and Sympatric species.	(same dian)
[9]	Natural and Artificial classification.	(Alls: 0:1)
[10]	Vertical and Horizontal classification	(Ans. 8.4.2)
[11]	Fungi and Bacteria.	(Ans. 8.10.)
[12]	Alone and Fundi	. (Ans. 8,10)
[13]	Alone and Bryonhyte and your a and so or may come	(Ans; 8,10)
[14]	a market and a FT and the confidence and the form	
[15]	Bryophyte and Pteridophyte.	(Ans. 8.10)
[16]		(Ans. 8.10)
[17]	1 1	(Ans. 8.10)
• E.	HOLLET TYPE Y	
	turns he to taink! Smale and se remember se	(Ans. 8,4.1)
[1]		
[2]		(Ans. 8.3.4)
[3]	an 1 1 ht	(condi meni)
[4]		(Ans. 8.4.1)
[5]		(Ans. 8,4.1)
[6]	Sittinghan of context on a found in the cohoma	(Ans. 8.3.3)
[7]	policis.	(Ans. 8.4)
[8]		(Ans. 8.8.1)
[9]		(Ans. 8.8.2)
[10]		(Ans. 8.8.3)
[11]	Bog moss Pinus	(Ans. 8.8.5)
		(Ans. 8.8.6)
[13		(Ans. 8.9.3)
[14		
• F	The first International Botanical Congress was held at Rochester / Paris / Sydney	·.
[1		
[2	Binomial nomenclature was proposed by be candone butter as a second of the control of the contro	
13	by De Candolle / Bentham / Hooker / Putter	าเกรดก
[4		
{5	A dinomycetes / Mycoplasma / Spin	rochaeta.
[6	The smallest prokaryot is Myxobacterium / Action years	
[7	Davidiomyceles / Phycomyceles	
[8]		
[9		
[10		
[11	VIETNIE / LINGUIGE	
[12	Bamboo belongs to the family commission syr	

220		
[13]	The jute fibres are secondary xylem fibres / phloem fibres.	
[14]	Lemon is rich is citric acid / tartaric acid / both.	
[15]	Yeast's life cycle is haplobiontic / diplobiontic / both.	
[16]	Isomorphic alternation of generation is found is Polysiphonia / Dryopteris / Ectocarpus.	
[17]	Heteromorphic alternation of generation is found in Dryopteris / Pogonatum / both.	
[18]	Triphasic alternation of generation is found in Polysiphonia / Dryopteris / Ectocarpus.	
• G.		
	Scientific names are always written in	
[1]	first gave the classification of animals.	
[2]	The state of the s	
[3]	first gave the classification of plants.	
[5]	Primitive plants have chromosomes.	
[6]	The book written by Englar and Prantl is	
[7]	The book written by Hutchinson is	
[8]	The last ICBN session was at in	
[9]	The cancer causing virus contains as the nucleic acid.	
[10]	The soil borne generally liberates antibiotics.	
[11]	The are called amphbious plants.	
[12]	The are true vascular cryptogams.	
	Gymnosperms are so called because they have	
	The most developed gymnosperm is	
[15]	Heterosporous condition in pteridophyte is found in	
[16]		
[17]	The intermediate between thalloid and leafy bryophyte is	
[18]		
[19]	The enzyme is considered as the anti-aging factor of Spirulina.	
[20]		
[21]		
	Marsilea hasleaves.	
[24]	Bamboo has internodes.	
[25]		
[26]	A STATE OF THE STA	
• H.	Put ✓ Marks on Yes / No :	
[1]	Takhtajan gave the natural system of classification. —Yes/No. Super class is a bigger division than sub-class. —Yes / No.	
[2]	Hutchinson divided Dicotyledons into Lignosae and Herbaceae. —Yes / No.	
[3]	The rules of plant nomenclature is dated back to 1758. —Yes / No.	
[5]	The natural system of classification was published in Genera Plantarum. —Yes / No.	
[6]	Bracketed key are better tools in comparison to indented key. —Yes / No.	
[7]	The uniform bio-code was started in 1994 in TokyoYes / No.	
[8]	Viruses are intermediate between plants and animals. —Yes / No.	
[9]	Chlamydia is the largest virus. —Yes / No.	
[10]	Algae may be both prokaryotic and eukaryotic in nature. Yes / No.	
[11]	Fungi contain chitin in their cell wall. —Yes / No.	
[12]	Bryophytes are vascular cryptogams. —Yes / No.	
[13]	Pteridophytes have independent sporophyte and gametophyte —Yes / No.	
[14]	Gymnosperms always have cones as their reproductive structures. —Yes / No	
[15]	Angiosperms may have one or two cotyledoned seed. —Yes / No.	
[16]	Mosses are the primitive broyphytes. —Yes / No.	
[17]	Ferns are homosporous in nature. —Yes / No.	
[18]	Spirulina is a blue green algae containing high percentage of protein. —Yes / No.	
[19]	Mushrooms belong to class Basidiomycetes. —Yes / No. Agaricus grow well in lower Bengal. —Yes / No.	
[20]	Agarteus grow well in lower beligar. — Tes / No.	

- [21] Bog moss is used as bandaging material. --- Yes / No.
- [22] Marsilea is a terrestrial fern. -Yes / No.
- [23] Pinus produces good quality timber. -Yes / No.
- [24] Bamboo belongs to family Cyperaceae. Yes No.
- [25] Triphaosic alternation is found in red algae. -Yes / No.
- 1261 Isomorphic alternation of generation is found in brown algae. -- Yes / No.
- [27] Yeast exhibits only the haploid status. -Yes / No.
- [28] Yeast represents a group of unicellular fungi. --- Yes / No.

Answers to Q. [F], [G] and [H]

- [F] [1] Paris. [2] Linnaeus. [3] tribe. [4] Hutchinson. [5] Phage. [6] Mycoplasma. [7] Nostoc.
 [8] Basidiomycetes. [9] Sphagnum. [10] Marsilea. [11] both. [12] Gramineae. [13] phloem fibres. [14] citric acid. [15] both. [16] Ectocarpus. [17] both. [18] Polysiphonia.
- [6] [1] Latin. [2] Aristotle. [3] dicotyledons; monocotyledons. [4] De-Candolle. [5] longer. [6] Die Natürlichen Pflanzen Families. [7] Taxonomy of Flowering plants. [8] Geneva. [9] RNA. [10] Actinomycetes. [11] bryophytes. [12] pteridophytes. [13] naked seeds. [14] Gnetum. [15] Selaginella. [16] Equisetum arwense. [17] Anthoceros. [18] Parallel. [19] super oxide-dismutase. [20] Agaricus. [21] Sphagnum. [22] quadrifoliate. [23] hollow. [24] Citric. [25] isomorphic. [26] Triphasic.
- [H] [1] No. [2] Yes. [3] Yes. [4] Yes. [5] Yes. [6] No. [7] Yes. [8] No. [9] No. [10] Yes. [11] Yes. [12] No. [13] Yes. [14] No. [15] Yes. [16] No. [17] Yes. [18] Yes. [19] Yes. [20] No. [21] Yes. [22] No. [23] Yes. [24] No. [25] Yes. [26] Yes. [27] No. [28] Yes.

9

Respiration

Topics Discussed: Introduction & Definition, Energy currency; Relationship between photosynthesis and respiration, Compensation point; Respiration & Combustion; Fundamental process of respiration; Cellular respiration; Respiratory substrate, Types of cellular respiration; Cellular site of respiration; Aerobic respiration & Anaerobic respiration, Pasteur effect; Crabtree effect; Extinction point; Photorespiration; A few comparisons.

9.1. Introduction

Respiration is one of the most important characteristics of life. All living organisms respire till death. When respiration is permanently ceased in an organism, it can be called dead. A continuous supply of energy is required for various activities of the living organisms. This is provided by the process of respiration in which the **potential energy** stored in the food materials is converted to **kinetic** (utilisable) energy by their oxidation.

Definition: Respiration is a process by which energy is released as a result of oxidation of food within a living organism.

9.2. Energy Currency

The food materials (carbohydrate, fat and protein) are the source of energy in the cell; the energy remains stored in the **covalent chemical bonds** of these compounds. During respiration, these compounds are oxidised and their covalent bonds are broken to release the energy stored in them. A part of the released energy is trapped in **high energy phosphate bonds** (~P) of adenosine triphosphate (ATP) which is formed by joining adenosine diphosphate (ADP) and inorganic phosphate (Pi). The energy stored in the ~P of ATP is used for various activities of a cell, *i.e.*, when energy is required, ATP is hydrolysed into ADP + Pi. Thus, ATP is the readily available form of chemical energy and hence, it is also called **energy currency** of a cell (Fig. 9.1).

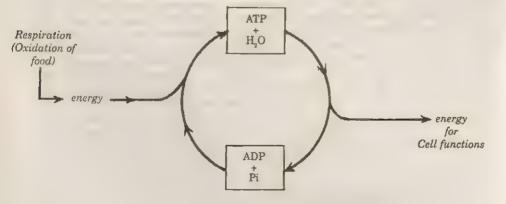


Fig. 9.1: ATP - the energy currency of cell.

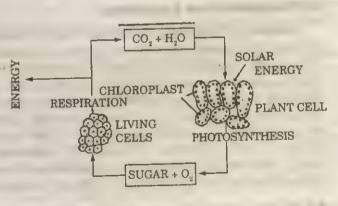
ATP was first isolated by **K. Lohmann** in 1929. He extracted it from muscle tissue. Its function in muscle was subsequently demonstrated by the famous physiologist **Albert Szent Gyorgyi** who showed that isolated muscle fibres contract when ATP is placed on them. Since then ATP has been shown to be the fuel driving many other biological processes *e.g.* muscle contraction, nerve impulse transmission, biosynthesis of several materials, secretion, active transport of materials across the cell membrane *etc.* ATP is found in all living cells and it is generally belived to be the universal supplier of energy in all biological systems, both in plants and animals. ATP provides the **vital link** between oxidation of foodstuffs and the energy requiring activities of an organism.

ATP contains two high energy phosphate bonds (\sim P) that are placed terminally and its structure may be represented as Adenosine – P \sim P \sim P. The published values for energy content in each \sim P of ATP vary between 7–8 kcal*. Here each \sim P will be assumed to be equivalent to 7.6 kcal (Reference—"Review of physiological chemistry", by Harold A. Harper, 13th Ed). Thus, during formation of each ATP from ADP + Pi, 7.6 kcal is captured and this amount of energy is released when ATP is hydrolysed to ADP + Pi, \sim 1.5 kcal is captured and this amount of energy is released when ATP is hydrolysed to

9.3. Relationship Between Photosynthesis and Respiration

Respiration is a **catabolic process** and is basically reverse of photosynthesis which is an **anabolic process**. During photosynthesis, CO_2 and H_2O are combined with the help of solar energy to form sugar, and O_2 is evolved. Conversely, respiration is a continuous process in which sugar is usually oxidised by O_2 and broken down into CO_2 and H_2O along with liberation of energy. Photosynthesis occurs only in chlorophyll containing cells (*i.e.* plant cells) during the day time (*i.e.* in presence of sunlight); whereas respiration occurs in all living cells, day and night. In green plants, during the

day time, the CO₂ produced by respiration is used up in photosynthesis; hence CO₂ is not evolved. Moreover, in the day time, the rate or photosynthesis becomes much more higher than the rate of respiration so that the CO₂ released in respiration is not adequate to meet the photosynthetic requirement. Hence,



during the day time, the Fig. 9.2: Energy transformation during photosynthesis and respiration. green plants absorb CO_2 from atmosphere and simultaneously add O_2 to the atmosphere because the O_2 released in photosynthesis exceeds the repiratory requirement. In this way, the green plants help in purification of the atmosphere (i.e. removal of CO_2 from and addition of O_2 to the atmosphere) during the day. However, this does not happen at night when there is no photosynthesis but respiration continues so that the green plants

^{*} Now a days energy is expressed in Joule (J) or kilojoule (KJ) units. In this book, kilocalorie (kcal) is used as the unit of energy because this is still more widely used. 1 kcal = 4.186 kJ.

9.4 Campanastana Pont

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9 t Respiration and Combustion

9.6. Fundamental Process of Beagmetion - External and Internal Beaginghes.

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9.5 the apprehion and I imbiselies

9.0 Cundemontal Process of Respushion - Colores and Internal

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Name of Concession, Name and Personal Property of Street, or other party of
                      many or present resignment of teachers and in fact, the party second
the same that the publisher with the publisher that
NAME AND ADDRESS OF THE OWNER, WHEN PERSON NAMED IN
NAME AND POST OFFICE ADDRESS OF THE OWNER, THE PARTY OF T
  NAME AND ADDRESS OF THE OWNER, OR OTHER DESIGNATION OF
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THE RESERVE AND PARTY AND PERSONS ASSESSMENT

REVISION

Potential energy-Stored energy which is not in usable form.

Kinetic energy—Free or utilisable energy which is available for doing some work. High energy phosphate bond—A phosphate bond in which extra energy remains stored and when the bond is split, this energy is released as free energy for doing some work.

ATP Adenosine triphosphate, a nucleotide made up of a purine base adenine, a pentose sugar and three phosphate bonds in series of which the last two are energy wich

Catabolic process Degradative process that releases energy.

Anabolic process-Synthetic or constructive process which absorbs energy.

Exergonic process—Energy liberating process.

Endergonic process-Energy absorbing (or consuming) process.

Respiration—The process of release of energy from oxidation of food within living cells.

Combustion Burning of fuels with emission of heat and often light.

Internal respiration—Biochemical process of oxidation of food within living cells for release of energy.

External respiration or Breathing-Physical process of gaseous exchange between organism and its environment.

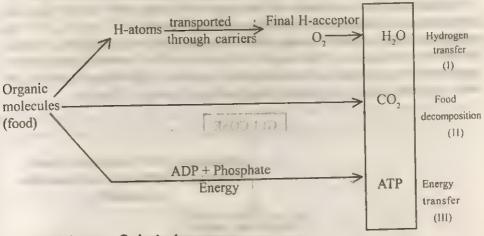
9.7. Cellular Respiration

Definition: The biochemical process of oxidation of food that occurs within the living cells for releasing the energy stored in it (food) is called cellular respiration.

This is also known as **biological** or **cellular oxidation**. It involves several biochemical pathways that are collectively referred to as **respiratory metabolism**. In this process, oxidation of food occurs very slowly in a stepwise and controlled manner under the influence of enzymes so that the reactions occur at a lower temperature (i.e. body temperature). In contrast to this, chemical oxidation or burning is a very rapid process that occurs at a much higher temperature because in this process, much heat is generated at a time. The chief purpose of biological oxidation is to release the energy stored in the food very slowly (i.e. in many steps) so that a part of it is captured in ATP and the remaining is liberated as heat. Since the heat is generated in many steps and not all at a time, an excessive rise of body temperature is prevented; otherwise, as a result of continual respiration, a living cell would be spontaneously burnt into ashes.

Cellular respiration involves reactions which yeild energy wherein the less stable organic materials (or food materials) containing more energy are decomposed to more stable end products that contain less energy. The energy released in respiration comes from the energy rich carbon bonds of the food molecules. The hydrocarbon groups (e.g. CH₄, CH₃ etc.) are energy rich and hence least stable whereas CO₂ is an anhydride (hydrogen-free compound) and hence is most stable. Cellular respiration comprises of three interrlated processes—(I) hydrogen transfer or redox phenomenon (i.e. oxidation of the food material by removal of H atoms and transfer of the H atoms to final H-accepter e.g. O₂ or any other compound which becomes reduced), (II) food decomposition (i.e. release of the carbon atoms of the food as CO₂), and (III) energy

transfer (i.e. formation or ATP from ADP, phosphate and the energy released from redox reactions). The basic mechanism of cellular respiration is summarised below:



9.8. Respiratory Substrate

Food materials stored in the protoplasm which are oxidised for liberation of energy in the process of respiration are called respiratory substrates or fuels of the cell. Carbohydrate, protein and fat are used as respiratory substrates and hence these are also called energy yielding food. Among these, glucose (a carbohydrate) is the chief fuel because it is the most easily available as well as utilisable food for majority of cells. Fat and protein may also be utilised in respiration. These are either converted to glucose or to a compound which is an intermediate product of glucose oxidation (breakdown) and then enter into the pathway of glucose oxidation. In certain cells, organic acids are used as respiratory substrates:

Under normal conditions, only carbohydrates are oxidised and this type of respiration is called **floating respiration**. However, in tissues rich in stored fats e.g. fatty seeds, adipose tissue etc. the fats supply the respiratory material. When carbohydrates and fats are completely used up and there is an acute shortage of fuel in the cell, the protoplasmic proteins serve as the respiratory substrate. This type of respiration is called **protoplasmic respiration** because the protein serves mainly as the body (or protoplasm) building material rather than as stored fuel. Thus, when protein is used as the respiratory substrate there is wasting of protoplasm.

9.9. Types of Cellular Respiration

Cellular respiration may be classified in two ways—(1) on the basis of the substrate used, and (2) on the basis of the nature of oxidation of the substrate. However, the latter classification in more widely used.

[1] Depending upon the type of substrate used, the cellular respiration has been divided into two types:

(i) Floating respiration—This occurs under normal conditions in which carbohydrates (glucose or other sugars) or fats are used as the respiratory substrate.

(ii) Protoplasmic respiration—This type of cellular respiration occurs under conditions of acute crisis caused by shortage of carbohydrates in which protoplasmic proteins are used up as the respiratory substrate.

[2] Depending upon the nature of oxidation of substrates, the cellular respiration may be of two types—(i) Aerobic respiration and (ii) Anaerobic respiration.

In aerobic respiration, molecular or free oxygen participates in the oxidative process so that the food (substrate) is completely oxidised, liberating CO₂ and H₂O as end products and large amount of energy. On the other hand, when the oxidation is carried out without participation of free oxygen, the process is called anaerobic respiration or anaerobiosis in which the food is incompletely oxidised so that the end products are lactic acid, ethyl alcohol etc. and only small amount of energy is liberated.

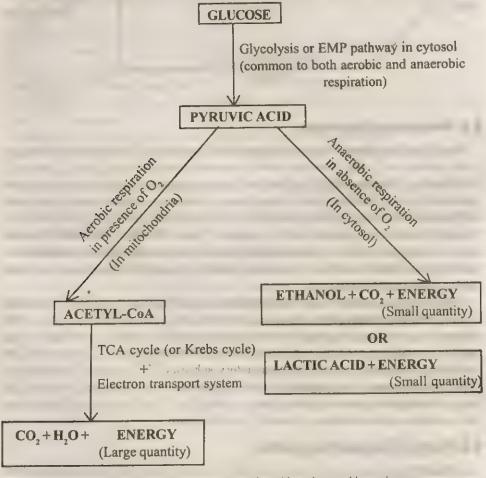


Fig. 9.3: Schematic representation of aerobic and anaerobic respiration.

The organisms which cannot survive without O_2 (i.e. which depend on aerobic respiration) are called **aerobes** whereas those which can respire anaerobically are called **anaerobes**. Anaerobes may be of two types:

(a) Facultative anaerobes (or partial anaerobes)—that can live both in presence or in absence of O, i.e. they can respire aerobically as well as anaerobically.

(b) Obligate anaerobes (strict or complete anaerobes) which survive only in O_2 free environment and are killed in presence of O_2 , *i.e.* they can respire only anaerobically.

9.10. Cellular Site of Respiration or Site of Cellular (Internal) Respiration

It has already been mentioned that respiration occurs in all living cells. The biochemical process or cellular oxidation involves several enzyme catalysed reactions. These enzymes are present in the cytosol (cytoplasmic matrix) and mitochondria of the cells. Thus, cytosol and mitochondria are the cellular (or better to say subcellular) sites of respiration.

The aerobic type of respiration involves both cytosol and mitochondria whereas the anaerobic respiration is restricted to the cytosol only. The cytosolic enzymes are capable of catalysing only such reactions that are responsible for incomplete breakdown of sugars in which very small amount of energy is released and oxidation by molecular

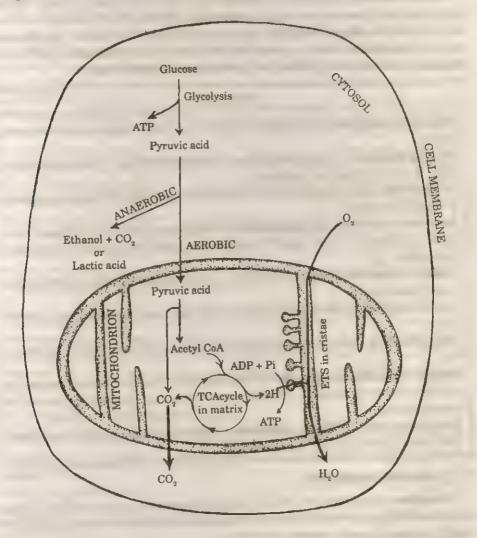


Fig. 9.4: Diagrammatic representation of the basic mechanism and site of cellular respiration. Oxygen does not take place. On the other hand, mitochondria contain the enzymes that are capable of capturing molecular O_2 and using it for complete oxidation of the products

formed by the cytosolic reactions into CO₂ and H₂O. The mitochondrial reactions are responsible for release of a large amount of energy and can occur in presence of molecular O₂ (i.e. in aerobic condition) only. This is the reason why the anaerobic respiration is an imcomplete process and is restricted to the cytosol only. In aerobic conditions, when molecular O₂ is plentiful, the end products of anaerobic reactions undertaken in cytosol enter into mitochondria for further and complete oxidation. Thus, the cytosol is involved in both anaerobic as well as aerobic respirations whereas mitochondria take part in aerobic respiration only. For obvious reasons, cells possessing large number of mitochondria exhibit aerobic type of respiration; whereas in those cells where mitochondria are scarce, the respiration is of anaerobic type.

It can be recalled that since mitochondria are the chief sites or energy release within the cells, these are also called **power house** of the cells. Prokaryotic cells are devoid of mitochondira; in these cells respiration is generally of anaerobic type. However, in some prokaryotes, there are specialised structures called **mesosomes** that contain respiratory enzymes and function as the **substitute of mitochondria**.

REVISION

Respiratory substrate—Food matters oxidised in cellular respiration for releasing energy.

Floating respiration—Cellular respiration in which the stored food like carbohydrate or fat is used as respiratory substrate.

Protoplasmic respiration—Cellular respiration in which the protoplasmic proteins are used as substrates.

Anaerobic respiration (or Anaerobiosis)—Cellular respiration in which molecular or free oxygen (O_2) is not used for oxidation i.e. which may occur in absence of atmospheric O_2 .

Aerobic respiration—Cellular respiration in which molecular (free) oxygen is used as the final oxidant.

Aerobes–Organisms that respire only aerobically and hence do not survive in absence of O_{γ} .

Anaerobes-Organisms that can respire anaerobically and can survive in absence of O.,

Partial (or facultative) anaerobes—Organisms that can survive both in presence as well as absence of oxygen, i.e. which can respire both aerobically as well as anaerobically.

Complete (or strict or obligate) anaerobes—Organisms that respire only anaerobically and cannot survive in presence of free Q_r

9.11. Aerobic Respiration

Definition: The process of cellular respiration in which food is completely oxidised to carbon dioxide and water by molecular oxygen so that the total energy stored in the food is released, is called aerobic respiration.

Site of aerobic respiration: Aerobic respiration occurs in most of the eukaryotic cells starting from unicellular organisms to those found in higher plants and animals. It is carried out by the joint action of the enzymes present in cytosol and mitochondria

of these cells. This type respiration usually does not occur in certain eukaryotic cells such as yeasts, RBC, skeletal muscle cells *etc.* in which mitochondria are either absent or very scarce. Prokaryotic cells, being devoid or mitochondria, do not exhibit acrobic respiration to a great extent.

Process of aerobic respiration (xxx)

Glucose is the chief food oxidised within the cell. Other sugars (fructose, galactose etc.), glycogen, starch, proteins and fats may also be oxidised in some cases. Plant cells utilise glucose and starch (a polysaccharide made up of glucose units), whereas animal cells utilise glucose and glycogen (another polysaccharide made up of glucose and popularly known as animal starch) as their main respiratory fuels. Considering glucose $(C_6H_{12}O_6)$ as a substrate, the **net reaction** of aerobic respiration can be represented by the following equation—

 $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + energy.$

Thus, for complete oxidation of each molecule of glucose, 6 molecules of O₂ are required and as a result of it 6 molecules of each, CO₂ and H₂O are produced. In aerobic respiration, one mole or gram molecular weight (i.e. 180 gm) of glucose can yield 686 kcal of energy.

From the above equation it appears that the $6O_2$ used in this reaction oxidises 6C of glucose to produce $6CO_2$. Although oxidation of carbon atoms of organic compounds by molecular O_2 to produce CO_2 is possible chemically (i.e. in chemical combustion or burning), it does not occur in biological oxidations. In aerobic respiration (i.e. biological oxidation by molecular O_2), what happens actually is that the molecular oxygen oxidises the hydrogen atoms to produce H_2O_2 , and the CO_2 is liberated by decarboxylation reactions. In the above equation, we find that, for production of $6CO_2$, 6 atoms of C and 12 atoms of O are needed, of which the glucose contains only 6 atoms of C and O each. So, 6 more O atoms are required. This comes from water present in the reaction medium (i.e. protoplasm). Thus, the actual reaction of complete oxidation of glucose in aerobic respiration should be represented as—

 $C_6H_{12}O_6 + 6O_2 + 6H_2O \longrightarrow 6CO_2 + 12H_2O + energy.$

The whole process of aerobic oxidation of carbohydrate, fat and protein is very complicated and involves a number of metabolic pathways as described below. Carbohydrate being the chief respiratory substrate, the process of its oxidation is discussed in detail whereas the processes of oxidation of fat and protein are dealt with briefly.

9.12. Oxidation of Carbohydrates

The main pathway of complete oxidation of carbohydrates is divisible into 3 phases—(I) glycolysis, (II) tricarboxylic acid cycle and (III) terminal respiration or electron transport system.

9.12.1. GLYCOLYSIS

Definition: The term glycolysis refers to the process of breakdown of carbohydrates to pyruvic acid.

This term was originally coined to indicate breakdown or lysis of glycogen which occurs in skeletal muscles. However, later it was revealed that other carbohydrates are also degraded by the same pathway in various cells. Glycolysis is also known as

Embden-Meyerhof-Parnas (in short EMP) pathway after the names of the scientists who described it.

Glycolysis is the preliminary pathway for catabolism or carbohydrates. In this process, the 6-C units (hexoses) are simply broken into two 3-C compounds (pyruvic acid) and none of the C atoms is freed as CO₂. Oxidation is carried out in one of the steps by removal of 2H atoms and only a small amount of energy is released. The H atoms are carried by certain carrier (nicotinamide adenine dinucleatide or NAD) which itself becomes reduced (NADH₂). As the stock of NAD in the cell is not unlimited, the NADH₂ must b oxidised to regenerate the NAD so that the process of glycolysis may continue. This (reoxidation of NADH₂) may be accomplished by molecular oxygen through the electron transport system in aerobic condition as well as without oxygen in anaerobic condition.

Glycolysis is generally considered as an anaerobic process because it does not directly involve oxidation by molecular oxygen and can also proceed in absence of oxygen. It occurs in both aerobic as well as anaerobic conditions, *i.e.* the glycolytic pathway is common for both aerobic and anaerobic types of respiration. In aerobic condition, the end product of glycolysis is pyruvic acid; whereas in anaerobic condition, the pyruvic acid is further converted to lactic acid or ethyl alcohol. Conversion of pyruvic acid to lactic acid or ethyl alcohol is also included in glycolysis.

Site of glycolysis:

Earlier it was believed that glycolysis occurs in yeasts and skeletal muscles only. But later it was revealed that this is carried out by almost all living tissues. The enzymes responsible for glycolysis are present in the cytosol (i.e. the cytoplasmic fluid matrix) of the cells, which therefore is the site of glycolysis within the cells.

Pathway of glycolysis:

Glucose is the starting material for glycolysis in majority of the cells (both in plants and animals). Glycolysis may start from starch in plant cells, and glycogen in animal tissues like muscles, adipose tissue, liver, leucocytes etc. Hexose sugars e.g. fructose, galactose etc. may also be catabolised by this pathway in certain animal tissues like liver.

The pathway of glycolysis is shown in Fig. 9.5. For being oxidised through this pathway, the hexose units are at first activated by phosphorylation (i.e. addition of phosphate group) because it proceeds through a number of phosphorylated intermediates.

Glucose enters into the glycolytic pathway by phosphorylation to glucose-6-phosphate. This reaction is catalysed by the enzyme hexokinase requiring ATP as phosphate donor and Mg⁺⁺ as cofactor. The glucose-6-phosphate is then converted to fructose-6-phosphate by the enzyme phosphohexose isomerase followed by another phosphorylation by ATP, catalysed by the enzyme phosphofructokinase in presence of Mg⁺⁺ to produce fructose-1, 6-diphosphate (also called fructose-1, 6-bisphosphate). This hexose diphosphate is then split by the enzyme aldolase into two triose phosphates, glyceraldehyde-3-phosphate and dihydroxyacetone-1-phosphate which are interconverted by the enzyme phosphotriose isomerase.

Glycolysis proceeds by oxidation of glyceraldehyde-3-phosphate, and because of the presence or phosphotriose isomerase, the dihydroxyacetone-1-phosphate also follows the same path. Oxidation of glyceraldehyde-3-phosphate is accompanied by its phosphorylation to produce 1,3-diphosphoglyceric acid, the reaction being catalysed

by the enzyme glyceraldehyde-3-phosphate dehydrogenase. In this reaction, oxidation is accomplished by removal of 2H atoms by NAD which becomes reduced to NADH₂, and inorganic phosphate (Pi or H₁PO₄) is the phosphate donor.

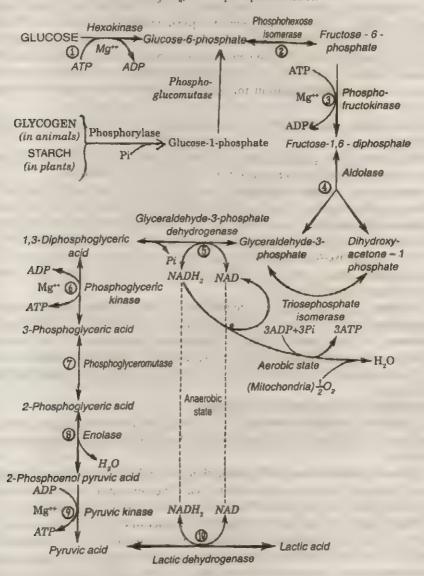


Fig. 9.5: Pathway of glycolysis.

In the next step, 1,3-diphosphoglyceric acid is converted to 3-phosphoglyceric acid by transferring the high energy phosphate from its first carbon to ADP to from ATP by the action of the enzyme phosphoglyceric kinase requiring Mg⁺⁺. Formation of ATP by a direct transfer of high energy phosphate from a phosphorylated intermediate to ADP is called substrate level phosphorylation. As 2 molecules of triose phosphates are formed per molecule of glucose, 2 molecules of ATP are generated in this step per molecule of glucose.

3-phosphoglyceric acid is converted to **2-phosphoglyceric acid** by the enzyme phosphoglyceromutase. The 2-phosphoglyceric acid is then dehydrated by the enzyme enolase to form **2-phosphoenol pyruvic acid**. Finally, the energy rich phosphate of the 2-phosphoenol pyruvic acid is transferred to ADP by the enzyme pyruvic kinase in presence of Mg' to form ATP, leaving the pyruvic acid. Formation of ATP in the pyruvic kinase reaction is another example of substrate level phosphorylation. In this step also, 2 molecules of ATP are generated per molecule of glucose oxidised. Thus, for each molecule of glucose, 2 molecules of pyruvic acid are formed at the end of glycolysis. The overall equation for glycolysis (breakdown of glucose to pyruvic acid) is acid is acid is acid.

Although most of the glycolytic reactions are reversible, three of them catalysed by

hexokinase, phosphofructokinase and pyruvic kinase are irreversible.

Breakdown of starch or glycogen through glycolysis is initiated by the action of the enzyme phosphorylase which splits the terminal glucose units of starch or glycogen as glucose-1-phosphate by phosphorolysis (i.e. lysis by adding phosphate group). In this reaction, Pi is required as phosphate donor. The glucose-1-phosphate is then converted to glucose-6-phosphate by the enzyme phosphoglucomutase (which shifts the phosphate group from 1st to 6th carbon of glucose) so that it may enter the glycolytic path described before.

Fructose may enter the glycolytic pathway on being phosphorylated to **fructose-6-phosphate** by the enzyme *hexokinase* requiring ATP and Mg⁺⁺. For oxidation of **galactose**, it is first phosphorylated to **galactose-1-phosphate** by the action of a specific enzyme *galactokinase* requiring ATP and Mg⁺⁺. Galactose-1-phosphate is then converted to glucose-1-phosphate through complicated reactions and enters the pathway

of glycolysis.

Significance (or importance) of glycolysis:

[1] Primary oxidative pathway: Glycolysis is the common primary pathway for oxidation (catabolism) of different carbohydrates in both aerobic and anaerobic condtions.

[2] Energy release and ATP production: Glycolytic process helps to release a part of the energy stored in carbohydrate food. The amount of ATP produced in this process depends upon the type of food being oxidised and the availability of $\rm O_2$.

When glucose or fructose is oxidised in presence of O_2 (i.e. in aerobic condition): 2 ATP are initially consumed (1 ATP each in hexokinase and phosphofructokinase reactions). 4 ATP are produced in the two substrate level phosphorylations catalysed by phosphoglyceric kinase and pyruvic kinase (1 ATP in each reaction for each triose; so, 2 ATP in each step for 1 molecule of glucose). Further, the NADH₂ produced in the glyceraldehyde-3-phosphate dehydrogenase reaction generates 3 ATP when oxidised through electron transport system (ETS) in presence of molecular O_2 [this will be discussed later]. So, 6 ATP (3 × 2) are produced for the two trioses formed from each glucose. Thus, the net gain is 4 + 6 - 2 = 8 ATP per glucose molecule oxidised.

When glycogen or starch is oxidised in aerobic condition: For each glucose unit, the production of ATP is same *i.e.* 4 + 6 = 10 ATP, but the consumption is only 1 ATP (since hexokinase reaction is not required). Thus, the net gain for oxidation of

each glucose unit of starch or glycogen -4+6-1=9 ATP.

In anaerobic condtion, the ETS does not operate; hence no ATP is produced from oxidation of NADH, and the net gain of ATP is lowered. In this condition, the net gain per glucose molecule is 4-2=2 ATP and that for each glucose unit of starch or glycogen is 4-1=3 ATP only.

[3] Formation of fats and amino acids: Some of the products of glycolytic pathway are used in synthesis of fats and amino acids. The dihydroxyacetone phosphate formed by the aldolase reaction of glycolysis can be converted to glycerol which is a component of fats. The pyruvic acid and its carboxylation product oxaloacetic acid may produce the amino acids alanine and aspartic acid respectively.

9.12.2. TRICARBOXYLIC ACID CYCLE [in short TCA cycle]

Definition: The cyclic, final common pathway for oxidation of carbohydrate, fat and protein through which acetyl coenzyme A (acetyl CoA) is completely oxidised to carbon dioxide and ultimately water, is known as tricarboxylic acid (TCA) cycle.

The TCA cycle is so named because it proceeds through the formation of a few tricarboxylic acids, i.e. acids containing three carboxyl (-COOH) groups, in the first few steps. Among these, the first product is citric acid; hence the cycle is also called citric acid cycle. This cyclic pathway is popularly known as Krebs cycle after the name of a renowned English biochemist Sir Hans Krebs who first (in 1937) described it as the pathway for complete oxidation of pyruvic acid.

Unlike the glycolytic pathway, TCA cycle can operate in aerobic condition only. Although TCA cycle is considered as the pathway of complete oxidation of acetyl CoA to CO2 and H2O, in fact H2O is not produced in this cycle; it simply degrades the acetyl CoA to release CO, and H atoms. The H atoms released in several steps of this pathway are carried by NAD or FAD which becomes reduced to NADH, or FADH,. These reduced carriers are reoxidised by transferring the H atoms to molecular O2 through the ETS so that the NAD or FAD is regenerated and H2O is produced. In absence of O2, as the ETS is inoperative, regeneration of NAD and FAD is not possible, and the TCA cycle stops immediately. Thus, in spite of the fact that oxidation reactions of TCA cycle are carried out by dehydrogenation (and not by molecular O2), the TCA cycle is regarded as an aerobic process because of its dependence on ETS which essentially requires the presence of O,.

Site of TCA cycle:

TCA cycle operates in all living tissues in which the respiration is of aerobic type. In contrast to the enzymes responsible for glycolysis, the complete set of enzymes responsible for the reactions of TCA cycle is located in mitochondria, mostly in the matrix, close to the enzymes of ETS. The functional significance of location of these two sets of enzymes within mitochondria is obvious.

Pathway (or reactions) or TCA cycle:

The basic plan of TCA cycle is as follows: acetyl CoA, a 2-C compound, combines with a 4-C compound, oxaloacetic acid (OAA), to form a 6-C compound, citric acid. The citric acid is subsequently degraded through a series of reactions which liberate CO2 and H atoms, and finally regenerate OAA. Therefore, the OAA functions in a catalytic manner in the complete oxidation of acetyl CoA through TCA cycle.

For complete oxidation of carbohydrates, the pyruvic acid formed as a result of glycolysis has to enter the TCA cycle. Before pyruvic acid can enter the TCA cycle, it

must be converted to acetyl CoA by oxidative decarboxylation. The reaction is catalysed by a multienzyme system known as pyruvic dehydrogenase complex present in mitochondria which requires thiamine pyrophosphate (TPP), lipoic acid, NAD and coenzyme A (CoA-SH) as coenzymes. In this reaction, CO_2 and 2H atoms are removed from pyruvic acid (which is thus decarboxylated and oxidised) and CoA-SH is added to the resulting 2-C compound to form acetyl CoA. The 2H atoms are carried by NAD as NADH₂ which is reoxidised by molecular O_2 through ETS to generate 3 ATP. Thus, for each hexose unit, $2 \times 3 = 6$ ATP are generated in this step. Acetyl CoA may also be derived from oxidation of fatty acids that will be discussed later. Oxaloacetic acid (OAA), the other starting material for TCA cycle is formed mainly by carboxylation of (i.e. addition of CO_2 to) pyruvic acid, the reaction being catalysed by the enzyme pyruvic carboxylase. OAA may also be derived from deamination or transamination of aspartic acid (an amino acid). However, it should be noted that the reactions responsible for the production of acetyl CoA and OAA are not included in the TCA cycle proper.

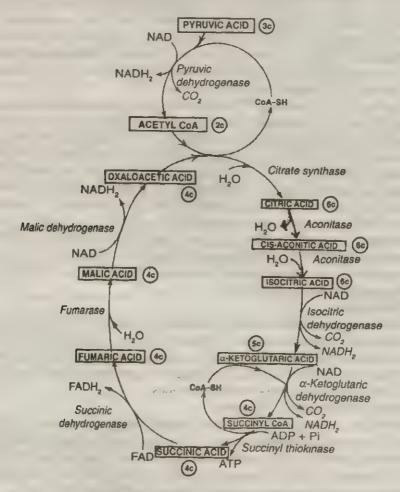


Fig. 9.6: Krebs TCA cycle.

TCA cycle begins with formation of citric acid by combination of acetyl CoA and OAA, the reaction being catalysed by the enzyme citrate synthase. In this reaction,

water is consumed and coenzyme A is freed which can be reused in the formation of acetyl CoA. Citric acid is converted to isocitric acid by the enzyme aconitase through the formation of cis-aconitic acid as an intermediate compound. Isocitric acid undergoes dehydrogenation followed by decarboxylation to form a 5-C compound, α -Keto glutaric acid. The enzyme required is isocitric dehydrogenase which uses NAD as the hydrogen acceptor. In this reaction, oxalosuccinic acid is produced as an intermediate compound and NAD is reduced to NADH, which on being reoxidised through ETS generates 3ATP. Next, α -ketoglutaric acid is oxidatively decarboxylated to succinyl-CoA. This reaction is analogous to the oxidative decarboxylation of pyruvic acid to acetyl-CoA and is catalysed by a multienzyme system called α -ketoglutaric dehydrogenase complex which also requires TPP, lipoic acid, coenzyme A and NAD as coenzymes. The NADH, produced in this reaction generates 3 ATP when oxidised through ETS.

TCA cycle proceeds by conversion of succinyl CoA to succinic acid in presence of the enzyme succinyl (or succinic) thiokinase. In this reaction, the CoA-SH is freed so that it can be reused and 1 ATP is produced from ADP and Pi by substrate level phosphorylation. In the remaining part of TCA cycle, the 4-C compound succinic acid is converted back to OAA through two dehydrogenations separated by a hydration. The first dehydrogenation reaction is catalysed by succinic dehydrogenase which uses FAD (flavin adenine dinucleotide) as hydrogen acceptor to produce FADH, and fumaric acid. The FADH, generates 2ATP while reoxidised through ETS. Fumaric acid is then hydrated (i.e. water is added to it) to form malic acid under the influence of an enzyme called fumarase. Finally, the malic acid is again dehydrogenated by a NAD requiring enzyme malic dehydrogenase to regenerate OAA. NADH, produced in this reaction also generates 3 ATP during its reoxidation through ETS.

Although most of the reactions of TCA cycle are reversible, the cycle operates unidirectionally because two reactions catalysed by the enzymes citrate synthase and α -keto glutaric dehydrogenase complex are irreversible. In addition, the conversion of pyruvic acid to acetyl CoA. *i.e.* the action of the enzyme pyruvic dehydrogenase is also irreversible.

The overall equation for complete degradation of pyruvic acid through TCA cycle is—

 $CH_3COCOOH + 2H_2O + 4NAD + FAD + ADP + Pi \longrightarrow$

(pyruvic acid) 3CO₂ + 4NADH₂ + FADH₂ + ATP

But if we consider the TCA cycle proper beginning from acetyl CoA, the equation will be-

Significance of TCA cycle:

[1] ATP production: TCA cycle is very important for ATP production. In this pathway, 12 ATP are produced for complete oxidation of each molecule of acetyl CoA as shown below:

Oxidation in ETS of $3NADH_2$ produced in the reactions catalysed by isocitric dehydrogenase, α -ketoglutaric dehydrogenase and malic dehydrogenase generate $3 \times 3 = 9$ ATP (@ 3ATP per $NADH_2$). FADH₂ produced in the succinic dehydrogenase

reaction generates 2 VTP. Success thickmase reaction produces 1 VTP by substrate level pl., phorylation. Therefore, total VTP production $9 * 2 + 1 \approx 12$.

[2] I mal common path of catabolism: TCA cycle is the final common pathway for the complete catabolism of carbohydrate protein and fat. All these energy yielding foods: it ultimately enter into this pathway for their complete oxidation. Carbohydrates enter into the TCA cycle through pyringic acid as described above. Entry of fat and protein into the TCA cycle will be discussed under oxidation of fats and proteins.

[3] Synthesis of porphyrins: Succinvl CoA produced in TCA cycle is required for synthesis of porphyrin compounds such as hemoglobin (in animals) and chlorophyll (in plants).

[4] Link between carbohydrate and protein metabolism: TCA cycle links carbohydrate and protein metabolism. The \alpha ketoplutaric acid produced in TCA cycle from carbohydrates can be transaminated to an amino acid, glutamic acid, which is incorporated in the proteins. Conversely, amino acids on entering the LCA cycle through their keto-deriv tuves ultimately form oxaloacetic acid which by decarboxylation produces pyruvic acid. The pyruvic acid may be converted to glucose through inverse glycolysis or neoglucogenesis.

• Why the TCA cycle is considered as an amphibolic pathway?

The term 'amphibolic pathway refers to a metabolic pathway which plays a dual role, cataloolic as well as anabolic. If A cycle is considered as an amphibolic pathway because it has both catabolic and anabolic functions.

Catabolic function- ICA cycle serves as the final common path for catabolism (oxidation) of carbohydrates, lipids and proteins to produce CO, H₂O and AIP.

Anabolic function -Intermediates of TCA cycle are utilised for synthesis of various compounds such as glucose (for neoglucogenesis), non-essential amino acids, fatty acids, cholesterol and porphyrins.

9.12.3. TERMINAL RESPIRATION

Definition: I eriminal respiration is the final phase of aerobic respiration in which the H atoms removed from the substrates by the action of dehydrogenases in glycolysis, IC texcle etc. are transferred through a series of enzyme carrier systems to molecular O so as to complete the process of biologic oxidation.

He sequence of enzymes and carriers responsible for transport of H atoms or electrons (reducing equivalents) from a substrate to molecular O₂ is called **electron** transport system (FTS) or respiratory chain (Fig. 9.7)

Site of terminal respiration:

Terminal respiration is carried out in the inner membrane of **mitochondria** which contains the enzymes of LTS. It can be recalled that mitochondria also contain the enzymes (dehydrogenases) of LCA cycle and β-oxidation that are responsible for producing the reducing equivalents.

Components of FTS and mechanism of terminal respiration:

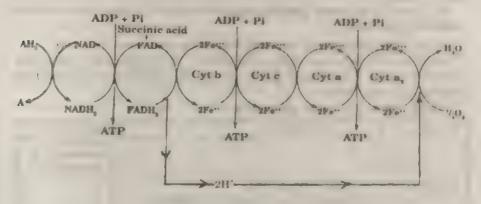
The major components (enzymes) of the respiratory chain are of three groups as follows:-

[1] Pyridinoproteins—These are dehydrogenases using NAD (meotinamide adenine dinucleotide) or NADP (meotinamide adenine dinucleotide phosphate) as coenzyme.

The NAD and NADP are derivatives of macin (or meeting acid), a member of vitamin B group, and can carry 2H atoms.

[2] Flavoproteins—These are dehydrogenases having FAD (tlas in adenine dinucleotide) or FMN (flavin mononucleotide) as '2H' carrier prosthetic proup 1 AD and FMN are derivatives of vitamin B (riboflavin)

[3] Cytochromes—These are iron-containing hemoproteins in which the iron remains as ferric (Fe'') or Ferrous (Fe'') ion. Several cytochromes are known to occur in the FTS e.g. cytochromes b, c, a and a, Fach cytochrome can carry one electron (e.) only, hence a pair of cytochromes are involved at each step of electron transport. Among these cytochromes, only the cytochrome a is capable of combining with molecular O₂ and transferring electron to it, this is the last member of LTS and is also called cytochrome oxidase.



Pig. 9.7: Electron transport chain

Each component of the respiratory chain remains as a reduction-oxidation (or redox) system. They become reduced on receiving reducing equivalents and again oxidised by transferring the reducing equivalents to the next member of the chain. When oxidation is catalysed by a dehydrogenase containing NAD as coenzyme, the NAD takes up 2H atoms from the substrate and becomes NADH, which in turn is reoxidised by transferring the 2H atoms to the next carrier FAD to make it FADH. In the remaining portion of the respiratory chain, only electrons are carried through the cytochromes and the 2H ions remain in the medium. The oxidised cytochrome containing Fe'' becomes reduced on accepting an electron (e) and the reduced carrier (Fe'') is reoxidised by transferring the e-to-the next member of the chain. Finally, the last member of the ETS, the cytochrome a_i (or cytochrome oxidase), transfers the e-to-molecular O_i ($\frac{1}{2}$ O.) which also takes up the 2H' from the medium to from water ($2e^i + 2H^o + \frac{1}{2}$ O. \Rightarrow H₂O).

During the transfer of reducing equivalents through the LTS, some energy is released in each step. However, only in limited number of steps in which the energy release is sufficient to phosphorvlate ADP, approximately 7.6 kcal of energy is captured by forming ATP from ADP and Pi (ADP + Pi \rightarrow HO). Formation of ATP through the ETS is called **oxidative phosphorylation** because in this process, phosphorylation of ADP is coupled with oxidation. In oxidation reactions catalysed by NAD containing

enzymes (i.e. when ETS begins from NAD), 3 ATP are produced; whereas in those reactions catalysed by FAD containing enzymes, only 2ATP are generated because in

the latter case, one oxidative phosphorylation is by-passed.

The number of phosphorylations (i.e. number of mols of ATP formed from ADP and Pi) per atom of O consumed in the ETS is called P: O ratio which represents the efficiency of ETS in capturing energy. In case of NAD linked reactions such as those catalysed by isocitric dehydrogenase, malic dehydrogenase etc., the P: O ratio = 3, whereas in the reactions catalysed by FAD linked enzymes e.g. succinic dehydrogenase, the P: O ratio = 2.

Significance of terminal respiration or ETS:

[1] It completes the biological oxidations that are initiated by the dehydrogenases and regenerates the oxidised carriers e.g. NAD, FAD etc. so that these may be used again and again.

[2] It helps in oxidative phosphorylation which is the major source of ATP

production in the body.

9.12.4. BALANCE SHEET OF AEROBIC OXIDATION OF GLUCOSE

An account of consumption and/or production of ATP, H₂O, CO₂ and O₂ in complete (aerobic) oxidation of one mole of glucose through glycolysis, TCA cycle and ETS is given below in tabular form.

9.12.4.A. ACCOUNT OF ATP: ENERGETICS:

Process	Reaction	Number of ATP molecules produced (+) or consumed (-)
Glycolysis	 (i) Glucose → Glucose 6-PO₄ (ii) Fructose-6-PO₄ → Fructose-1,6-diphosphate (iii) 2 × (Glyceraldehyde-3PO₄ → 1, 3-Diphosphoglyceric acid) (in ETS) (iv) 2 × (1,3-Diphosphoglyceric acid → 3-phosphoglyceric acid) (v) 2 × (2-Phosphoenolpyruvic acid → pyruvic acid) 	-1 -1 $+ (2 \times 3) = +6$ $+ (2 \times 1) = +2$ $+ (2 \times 1) = +2$ $Total = +8$
Oxidative decarboxy-lation of pyruvic acid	2 × (Pyruvic acid → Acetyl CoA) (in ETS)	+ (2 × 3) = + 6
TCA Cycle	 (i) 2 × (Isocitric acid → α-Ketoglutaric acid) (in ETS) (ii) 2 × (α-Ketoglutaric acid → Succinyl CoA) (in ETS) (iii) 2 × (Succinyl CoA → Succinic acid) (in ETS) (iv) 2 × (Succinic acid → Fumaric acid) (in ETS) (v) 2 × (Malic acid → Oxaloacetic acid) (in ETS) 	$+ (2 \times 3) = + 6$ $+ (2 \times 3) = + 6$ $+ (2 \times 1) = + 2$ $+ (2 \times 2) = + 4$ $+ (2 \times 3) = + 6$
		Total = + 24
Net gain of A	TP per mole of glucose oxidised = $8 + 6 + 24 = 38$	

Efficiency of respiration: It means how much percentage of the total energy released during respiration per mole of the substrate oxidised is usuable or catputred in ATP for future use. It is given by the following formula—

Efficiency of respiration = $\frac{\text{Energy capture per mole of substrate oxidation}}{\text{Total energy release per mole of substrate oxidation}} \times 100$

When 1 mole of glucose is combusted in a calorimeter, to CO₂ and water, approximately **686 kcals** are liberated as heat; that means the total energy contained in glucose is 686 kcals/mole. But when oxidation occurs in tissues (*i.e.* during respiration), some of this energy is not lost as heat and is captured in high energy phosphate bonds of ATP (7.6 kcals/ATP). During complete oxidation of 1 mole of glucose, **38 molecules** of ATP are produced. Therefore, the total energy captured in ATP per mole of glucose oxidised is 38 × 7.6 = 288.8 kcals which is roughly **42%** of 686 kcals

$$\left(\frac{288.8 \times 100}{686} = 42.09\right)$$
. Thus, the energy capturing efficiency of biological

systems during complete oxidation of glucose *i.e.* efficiency of respiration is 42% and the remaining portion (58%) of the energy stored in glucose is lost as heat. However, in homeotherms, the energy lost as heat is not entirely wasteful because it helps to maintain the body temperature.

9.12.4.B. ACCOUNT OF H,O:

During oxidation of glucose, H_2O is consumed either directly through hydration reactions or indirectly through phosphorylation reactions (because in such reactions, the H_2O released by addition of Pi is consumed). H_2O is also produced either directly in dehydration reactions or indirectly through dehydrogenation reactions (by reoxidation of NADH₂ or FADH₂ through ETS). The account of H_2O given below does not include production of H_2O from oxidative phosphorylations (i.e. ADP + Pi \rightarrow ATP + H_2O) because these H_2O molecules do not originate from oxidation of the glucose molecule.

Process	Reaction	Number of H ₂ O molecules produced (+) or consumed (-)
Glycolysis	(i) 2 × (Glyceraldehyde-3-PO ₄ → 1,3-Diphosphoglyceric acid) through phosphorylation through ETS (ii) 2 × (2-Phosphoglyceric acid → 2 phosphoenol pyruvic acid)	$-(2 \times 1) = -2$ $+(2 \times 1) = +2$ $+(2 \times 1) = +2$ $Total = +2$
Oxidative decarboxy- lation of pyruvic acid	2 × (Pyruvic acid → Acetyl CoA) (in ETS)	+ (2 × 1) = + 2
TCA Cycle	(i) 2 × (Oxaloacetic acid → Citric acid) (ii) 2 × (Citric acid → Cis-aconitic acid) (iii) 2 × (Cis-aconitic acid → Isocitric acid) (iv) 2 × (Isocitric acid → α-Ketoglutaric acid) in ETS (v) 2 × (α-Ketoglutaric acid → Succiniql CoA) in ETS (vi) 2 × (Succinyl CoA → Succinic acid) through substrate level phosphorylation (vii) 2 × (Succinic acid → Fumaric acid) in ETS (viii) 2 × (Fumaric acid → Malic acid) (ix) 2 × (Malic acid → Oxaloacetic acid) in ETS	$-(2 \times 1) = -2$ $-(2 \times 1) = +2$ $-(2 \times 1) = -2$ $+(2 \times 1) = +2$ $+(2 \times 1) = +2$ $-(2 \times 1) = -2$ $+(2 \times 1) = +2$ $-(2 \times 1) = -2$ $+(2 \times 1) = +2$ $Total = +2$

9.12.4.C. ACCOUNT OF CO, PRODUCTION:

Process	Reaction n ve fe 1 1 10 2	Number of CO ₂ molecules produced
Glycolysis	Glucose → Pyruvic acid	0
Oxidative decarboxy- i lation of pyruvic acid	2 × (Pyruvic acid → Acetyl CoA)	$(2\times1)=2$
TCA Cycle	(i) 2 × (Isocitric acid → α-Ketoglutaric acid) (ii) 2 × (α-Ketoglutaric acid → Succinyl CoA)	$(2 \times 1) = 2$ $(2 \times 1) = 2$ $Total = 4$
∴ Total number	r of CO ₂ molecules produced per mole of glucose oxidised =	2 + 4 = 6.

9.12.4.D. ACCOUNT OF O, CONSUMPTION:

During aerobic oxidation of glucose, O₂ is used for reoxidation of NADH₂ and FADH₂ through ETS. One molecule of O₂ is used for reoxidation of 2 molecules of NADH₂ or FADH₂.

Process	Reaction	Number of O ₂ molecules consumed
Glycolysis	2 × (Glyceraldehyde 3-PO ₄ → 1,3-Diphosphoglyceric acid)	1
Oxidative decarboxy- lation of pyruvic acid	2 × (Pyruvic acid → Acetyl CoA)	1
TCA Cycle	 (i) 2 × (Isocitric acid → α-Ketoglutaric acid) (ii) 2 × (α-Ketoglutaric acid → Succinyl CoA) (ii) 2 × (Succinic acid → Fumaric acid) (iii) 2 × (Malic acid → Oxaloacetic acid) 	1 1 1 1 1 Total = 4

9.13. Oxidation of Fats

Fat stored in the adipose tissue may be utilised as the respiratory substrate. For this, fats are first hydrolysed into glycerol and fatty acids by the enzyme tissue lipase present in adipose tissue. Both glycerol and fatty acids may be oxidised in the adipose tissue or may be released into the blood stream from where they are picked up and oxidised by certain other tissues like liver, kidney, heart etc. Glycerol is converted to dihydroxyacetone -1-phosphate which enters the glycolytic pathway for being converted to pyruvic acid. Finally, the pyruvic acid is oxidised through TCA cycle. Thus, glycerol is oxidised through the pathway of oxidation of carbohydrates. Fatty acids are first oxidised and broken down into several acetyl CoA molecules through a process called β-oxidation. The acetyl CoA finally enters the TCA cycle for complete oxidation. Like the TCA cycle, the β-oxidation also produces NADH, and FADH, that

are oxidised through the ETS to generate ATP. The β -oxidation occurs in the mitochondrial matrix in **aerobic condition** only, because it is intimately linked with TCA cycle and ETS.

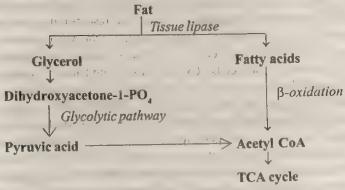


Fig. 9.8: Pathway of oxidation of fat in brief.

9.14. Oxidation of Proteins (or Amino acids)

Amino acids derived either from dietary proteins or from breakdown of tissue proteins may be used as respiratory substrates. For oxidation of amino acids, at first their amino groups are removed by a process of **deamination** (i.e. removal of the amino group as ammonia) or **transamination** (i.e. interchange of amino and keto groups between an amino acid and keto acid) to form corresponding keto acids. The resulting keto acid is either itself a component of TCA cycle or is converted to such a compound and thus it is oxidised completely to CO₂ and H₂O through TCA cycle.

REVISION

Glycolysis - Breakdown of sugars to pyruvic acid.

TCA cycle-The cyclic pathway for complete oxidation of acetyl-CoA.

Respiratory chain—The series of enzyme-carrier systems through which reducing equivalents are transferred to oxygen to complete biological oxidation.

Cytochromes—Iron containing hemoproteins that carry electrons in the respiratory chain (or ETS).

Substrate level phosphorylation-ATP formation without ETS.

Oxidative phosphorylation-ATP formation through ETS.

 $P: O\ ratio$ —Number of molecules of ATP produced per atom of oxygen consumed. β -Oxidation—Oxidation of fatty acids at β -carbon (i.e. the 3rd carbon from the carboxyl end) to liberate acetyl-CoA.

Deamination—Removal of NH₃ from an amino acid so that the amino acid is converted to the corresponding keto acid.

Transamination-Interchange of amino and keto groups between an amino acid and a keto acid.

9.15. Anaerobic Respiration or Anaerobiosis

Definition: The process of oxidation of food within living cells for release of energy without the participation of molecular oxygen is called anaerobic respiration.

Site of anaerobic respiration: Anaerobic respiration occurs mainly in microorganisms e.g. many bacteria, yeasts (fungi), Monocystis (a parasitic protozoa) etc. However, some higher plant cells (e.g. those of seeds, potato tubers etc.) and animal cells (e.g. skeletal muscle cells, RBC etc.) also exhibit anaerobic respiration. Cells that respire anaerobically do so either because they do not get sufficient O_2 or because they are unable to capture and use O_2 , due to lack of mitochondria in them.

Process of anaerobic respiration: As might be expected, the anaerobic type of respiration does not require participation of the ETS. Nevertheless, there are certain (very few) bacterial species that exhibit a special type of anaerobic respiration in which the ETS is involved. Thus, depending upon whether the ETS is involved, the process of anaerobic respiration may be of the following two types—(I) anaerobic respiration without ETS, and (II) anaerobic respiration with ETS. These processes are described below.

I. Anaerobic respiration without ETS:

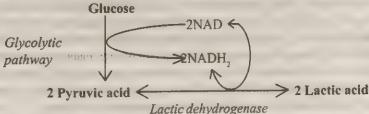
This is an energy yielding process of oxidation of food within the living cells in which neither molecular O₂ nor the respiratory chain (ETS) is involved and an organic compound is the final electron acceptor (oxidant). Thus, in this type of respiration, both the electron donor (respiratory substrate) and the electron acceptor are organic compounds.

In this process, food is incompletely degraded and naturally much less energy (only a part of that stored in the food) is released. In most of the cells respiring in this way, glycolysis is the common feature and it constitutes the main part of anaerobic respiration. As a matter of fact, glycolysis is the only ATP-generating oxidative process that can continue without the co-operation of ETS, whereas all other oxidative pathways e.g. Krebs cycle, β-oxidation etc. are stopped when the ETS is inoperative. In order to keep the glycolytic process running, a steady supply of NAD is necessary, which is required for the oxidation (dehydrogenation) reaction catalysed by the enzyme glyceraldehyde-3-phosphate dehydrogenase (see Fig. 9.5). For this, the NADH₂ produced in the above reaction of glycolysis is to be reoxidised to NAD. This is accomplised by transferring the 2H atoms of NADH₂ to pyruvic acid (or some derivative of it) produced at the end of glycolysis. Thus, an organic compound (pyruvic acid etc.) acts as the final oxidant and there is no net oxidation of food in this process.

In this type of respiration, since ETS is not operative, oxidative phosphorylation is not possible and the production of ATP occurs only by substrate level phosphorylation during glycolysis. Hence, very small quantity of ATP is produced. Nevertheless, the process is very important because it provides at least some energy to maintain the life or activity of certain cells of higher plants and animals during the period of crisis caused by a short supply of oxygen. However, some cells normally employ such a process of anaerobic respiration even in presence of oxygen because their energy requirement is not so high. As the ETS is not involved in the process, the reactions of it are restricted to the **cytosol** part of the cells. The processes of this type of anaerobic respiration occurring in higher animals, higher plants and micro-organisms are described below.

[1] In higher animals:

In the cells of higher animals, anaerobic respiration is accomplished by breakdown of glucose (or glucose units of glycogen) into two molecules of lactic acid, and approximately 47 kcal of energy is released per mole of glucose. It occurs in two phases. In the first phase, the glucose is oxidatively degraded to two molecules of pyruvic acid (CH₃COCOOH) through the glycolytic pathway described earlier. In this phase, the oxidation is carried out by dehydrogenation in which NAD acts as the oxidant (carrier of 2H atoms) and itself becomes reduced to NADH₂. The second and final phase consists of a single reversible reaction catalysed by the enzyme lactic dehydrogenase. In this reaction, the pyruvic acid is reduced to lactic acid by NADH₂. The entire process, called anaerobic glycolysis, can be summarised as follows:



Although no ATP is formed in the final phase (i.e. lactic dehydrogenase reaction) of anaerobic glycolysis, this reaction is very important because it helps in the regeneration of NAD so that the glycolysis may continue to operate and at least some ATP is formed. In this type of respiration (anaerobic glycolysis), there is a net gain of only 2ATP per mole of glucose oxidised (as described earlier under the heading 'significance of glycolysis'). The overall equation for the process is—

 $C_6H_{12}O_6 + 2Pi + 2ADP \longrightarrow 2CH_3CHOHCOOH + 2ATP + 2H_2O$ (glucose) (lactic acid)

Since, out of 47 kcal of energy liberated from each mole of glucose only 2ATP are formed, about 15.2 kcal is captured @ 7.6 kcal/ATP) in the process. Thus, the energy

capturing efficiency of the process of about 32%.

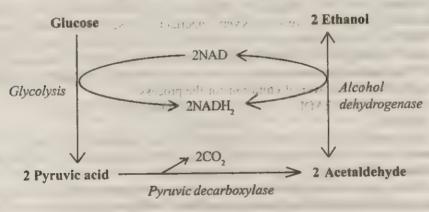
Some common examples of tissues (or cells) of higher animals respiring in this way are skeletal muscle, adipose tissuee, RBC, WBC etc. In skeletal muscle, there can be sudden demand for energy at a very low oxygen concentration, particularly during heavy exercise. This energy is supplied by a rapid breakdown of large amount of glycogen through anaerobic glycolysis. Skeletal muscle with its poor oxygen supply and relatively few mitochondria but high concentration of glycolytic enzymes is ideally designed for carrying out anaerobic glycolysis to meet its short-term ATP needs. In doing so, the exercising muscles produce relatively large amount of lactic acid, accumulation of which eventually causes fatigue of the muscles and termination of exercise.

It can be mentioned here that lactic acid formed in skeletal muscles is secreted into blood and transported to liver. In this organ, about 80% of the lactic acid is converted back to glucose by the process called inverse glycolysis (or neoglucogenesis) and returned to muscles for glycogen synthesis. The remaining 20% lactic acid is converted back to pyruvic acid and oxidised through TCA cycle to provide energy (ATP) for converting majority of the lactic acid back to glycogen. Reversal of anaerobic glycolysis is possible because most of the steps of this pathway are reversible and the three irreversible reactions of this sequence are by-passed due to the presence of separate enzymes.

Cells like RBC, WBC and those of adipose tissue respire by the process of anaerobic glycolysis because they possess very few mitochondria and require much less energy.

121 In higher plants:

Normally, most of the cells of higher plants respire aerobically so long as there is an adequate supply of oxygen, but they can respire and thus survive even in absence of oxygen for a short duration. During the anaerobic respiration of plants, glucose (or glucose unit of starch) is broken down into carbon dioxide and ethyl alcohol (ethanol) and small amount of energy is released. Two moles of each, CO, and ethanol, are produced and approximately 40 kcal of energy is released per mole of glucose. The entire process is divisible into two phases. In the first phase, a molecule of glucose is broken down into two molecules of pyruvic acid through the glycolytic pathway. The second phase comprises to two reactions by which the pyruvic acid is converted to ethanol. The pyruvic acid is first decarboxylated to acetaldehyde by the enzyme pyruvic decarboxylase. This reaction is irreversible. Finally, the acetaldehyde is reduced to ethanol by NADH,. This reversible reaction is catalysed by the enzyme alcohol dehydrogenase. Pyruvic decarboxylase is found in plant tissues and not in animals. This is why animals do not produce ethanol during anaerobic respiration. Because of the irreversible nature of the pyruvic decarboxylase reaction, in contrast to animals the end products of anaerobic respiration in plants i.e. ethanol and CO, cannot be converted back to glucose. The process can be summarised as follows:



Here also, no ATP is formed in the second phase i.e. in the conversion of pyruvic acid to ethanol. Yet the final reaction catalysed by alcohol dehydrogenase is very important because it regenerates the NAD required for maintaining the ATP generating process of glycolysis. In this process also, only 2ATP are formed per mole of glucose. Thus, out of the 40 kcal of energy liberated per mole of glucose, only 15.2 kcal @ 7.6 kcal/ATP) is captured, i.e. energy capturing efficiency of the process is 38%. The overall equation for the process is-

$$C_6H_{12}O_6 + 2Pi + 2ADP \longrightarrow 2CH_3CH_2OH + 2CO_2 + 2ATP + 2H_2O$$

(glucose) (ethanol)

In higher plants, anaerobic respiration can continue for a short period only, because of the following two probable reasons-(i) the energy released in the process is insufficient for maintaining the life processes for a long time and (ii) the alcohol accumulated as end product is toxic for the cells at higher concentrations. However, this type of respiration occurs in many seeds e.g. pea, gram, cereals etc. during the early stage of their germination before the seed coats are ruptured and in roots living in water lodgged soil. It also occurs in certain fruits e.g. grapes, apples etc. in which the suberised and cutinised skin does not allow oxygen to reach the respiring cells.

It is interesting to mention that some plant tissues like **potato tubers** normally respire anaerobically and produce **lactic acid** by the process described earlier in case of higher animals. This is possibly due to a lack of O₂ supply to these underground tissues.

[3] In micro-organisms: Fermentation:

Many micro-organisms such as a number of bacteria, yeasts (fungi), *Monocystis* (protozoa) etc. derive energy by employing the processes of anaerobic respiration in which ETS is not involved, similar to that occurring in higher animals and plants. This type of anaerobic respiration is called **fermentation** in case of micro-organisms. Although due to the similarity in the pathways, the anaerobic respiration of higher animals and plants is sometimes casually referred to as fermentation, the term fermentation is used particularly in reference to micro-organisms. The term fermentation literally means decomposition of organic compounds into simpler compounds through the agency of enzymes (ferments).

Definition of fermentation: Fermentation is the energy yielding process of anaerobic oxidation of organic compounds carried out by the enzyme action of microorganisms, in which neither gaseous oxygen nor respiratory chain is used and an organic

compound is the final oxidant.

Types of fermentations: Fermentation may be of various types depending on the compound being formed as end product. Among these, the two most common types are alcoholic fermentation and homolactic fermentation or lactic acid fermention in which ethanol and lactic acid are produced respectively.

[a] Alcoholic fermentation: The process of anaerobic breakdown or sugars to ethyl alcohol (ethanol) and CO_2 in micro-organisms is called alcoholic fermentation. In this type of fermentation, which occurs principally in yeasts and some other micro-organisms, glucose molecule is broken down into two molecules of ethanol and two molecules of CO_2 . The process of alcoholic fermentation is same as that of anaerobic

respiration in higher plants as described earlier.

In 1857, Louis Pasteur first described alcoholic fermentation in yeasts. He noted that fermentation takes place anaerobically and is sufficient to keep the yeast cells alive but they could divide only in presence of O₂. That means the yeast cells ordinarily respire by fermentation but during cell division they respire aerobically to meet the increased energy needs. Pasteur recognised that fermentation is catalysed by enzymes and his concept was that fermentation (i.e. enzyme action) is carried out by intact living cells only. But later, in 1897, Eduard Buchner succeeded in extracting enzymes from yeast cells and showed that such extracts could also carry out fermentation independently of the yeast cells. Previously it was believed that a fraction of yeast extract called 'zymase' was responsible for alcoholic fermentation. However, now it is known that the so called zymase was nothing but a mixture of enzymes responsible for glycolysis and conversion of pyruvic acid to ethanol.

[b] Homolactic fermentation or Lactic acid fermentation: The process of anaerobic breakdown of sugars to lactic acid in micro-organisms is called homolactic fermentation or lactic acid fermentation. This type of fermentation occurs in microrganisms like some lactic acid bacteria (responsible for souring of raw r

Monocystis etc. It is identical to anaerobic glycolysis occurring in skeletal muscle. In this type of fermentation, glucose or any other sugar molecule is degarded to two molecules of lactic acid as the sole end product. During souring of milk, lactic acid fermentation is brought about by certain bacterial e.g. Bacterium lactic acidi, Lactobacillus lactici and Bacterium acidi lactici (that are grouped as lactic acid bacteria) which cause conversion of lactose sugar of milk into lactic acid. For this, the lactose sugar (which is a disaccharide) is at first hydrolysed into the monosaccharide hexose sugars glucose and galactose. These hexose sugars then enter into the anaerobic glycolytic pathway to produce lactic acid.

• Special type of fermentations :

In some bacterial fermentations, butyric acid, propionic acid, acetic acid, succinic acid, acetone, butanol, etc. are formed as end products and accordingly these processes are called butyric acid fermentation, propionic acid fermentation, acetic acid fermentation, and so on.

[1] Butyric acid fermentation—Some obligate (strict) anaerobic bacteria like *Bacillus* butyricus and Clostridium butyricum are responsible for fermenting sugars and lactic acid into butyric acid as follows:

$$C_6H_{12}O_6 \longrightarrow C_4H_8O_2 + 2H_2 + 2CO_2$$

(Hexose sugar) (Butyric acid)
 $2C_3H_6O_3 \longrightarrow C_4H_8O_2 + 2H_2 + 2CO_2$
(Lactic acid) (Butyric acid)

The butyric acid fermentation also takes place in butter which has become **rancid** (i.e. stale and ill smelling).

[2] Propionic acid fermentation—In this type of fermentation by propionic acid bacteria (e.g. Propionibacterium), the product is propionic acid. For this, the pyruvic acid derived from sugars is reduced to propionic acid.

$$C_3H_4O_3 \xrightarrow{+2H_2} C_3H_6O_2 + 2H_2O$$
(Pyruvic acid) (Propionic acid)

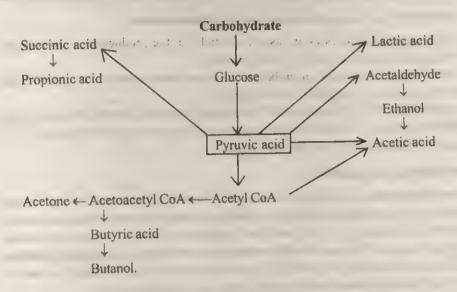
This type of fermetation takes place in the formation of Swiss cheese.

[3] Acetic acid fermentation—This is a special type of fermentation brought about by acetic acid bacteria such as Acetobactor aceti, Acetobacter xylinum etc. These bacteria utilise atmospheric oxygen and oxidise ethanol or pyruvic acid into acetic acid as follows—

$$\begin{array}{cccc} C_2H_5OH+O_2 & \longrightarrow & C_2H_4O_2 & + & H_2O \\ \text{(Ethanol)} & & & \text{(Acetic acid)} \\ 2C_3H_4O_3 & + & O_2 & \longrightarrow & 2C_2H_4O_2 & + & 2CO_2 \\ \text{(Pyruvic acid)} & & & \text{(Acetic acid)} \end{array}$$

Thus, acetic acid fermentation is unique in that it is an aerobic process while all other fermentation processes are anaerobic ones.

In fermentation reactions, glucose is the chief substrate; however other carbohydrates, amino acids and fatty acids may also be used as substrates. Pyruvic acid is the hub (or key intermediate) of carbohydrate fermentations in which the initial stage frequently but not always follows the scheme of glycolysis. Difference in carbohydrate fermentations usually occur in the ways the resulting pyruvic acid is metabolised as shown below:



It should be noted that the bacteria carrying out homolactic fermenation (in which lactic acid is the sole end product) are called **homofermentative**. In contrast to this, most bacteria produce several end products mentioned above, but no single species can produce all these products. These are called **heterofermentative bacteria**. In fact, bacteria are grouped on the basis of their products of fermentation e.g. lactic and group, propionic acid group etc. depending on the major product. The process of fermentation in heterofermentative lactic acid bacteria is called **heterolactic** or **mixed** lactic fermentation in which one molecule of each, lactic acid, ethanol and CO₂ are produced from each molecule of glucose.

Since, living organisms first arose in an atmosphere lacking oxygen, anaerobic fermentation is the most primitive type of biological mechanism for obtaining energy from the nutrient molecules. Higher aerobic organisms have evolved from anaerobic organisms and have retained the fermentation pathway for anaerobic degradation of glucose to pyruvate (i.e. glycolysis). Being able to utilise O₂, the aerobic organisms have developed additional mechanism that can complete the catabolism of pyruvate to CO₂ and H₂O.

Fermenation-extracellular or intracellular process ?

Earlier some people wrongly believed that fermentation was an extracellular process catalysed by the enzymes secreted by the micro-organisms into the medium. But now it is known that fermentation occurs **intracellularly** so that the micro-organisms may

derive their energy from it. The organic compounds formed as end products of fermentation are wastes for the micro-organisms as these are not catabolised further. These products are passed out of the cells into the medium. That is why the process of fermentation can continue for relatively longer period than anaerobic respiration in the cells of higher plants and animals. Although fermentation is usually an anaerobic process (i.e. does not require molecular O₂), it may occur even in presence of O₂.

Application (or economic importance) of fermentation:

(i) Fermentation processes are used industrially in the production of alcohol (in brewing), acetic acid (or vinegar), lactic acid etc.

(ii) Formation of curd from milk also involves fermentation of the milk-sugar

(lactose) into lactic acid by lactic acid bacteria.

(iii) Release of CO₂ from alcoholic fermentation by yeast is used in baking. Yeast is added to the flour and water and when the mixture is warmed, the escaping CO₂ causes the dough to swell and become spongy.

Putrefaction and Decay :

In addition to the common fermentations, there are some other fermentative processes in which proteins and other nitrogenous organic materials are decomposed anaerobically by bacteria producing H₂S, NH₃ and other incompletely oxidised compounds having disagreeable odour. Such anaerobic decomposition of proteins etc. is called **putrefaction** which is most commonly observed in the decomposition of dead bodies of animals or rottening of proteinaceous food of animal origin e.g. meat, fish, egg etc.

The term decay refers to gradual but complete decomposition of dead organic matters (or dead bodies) by microbial action so that the elements present in the organic matters are released in the environment for being recycled. Micro-organisms which promote decay are collectively known as decomposers which utilise oxygen for complete breakdown of the organic matters. Thus, putrefaction is an incomplete and anaerobic decomposition of organic matters whereas decay is a complete and aerobic decomposition of organic matters.

II. Anaerobic respiration with ETS:

This is a special type of anaerobic respiration that occurs occasionally in some bacteria only, and not in the cells of higher plants or animals. In this process, although oxygen is the final electron acceptor, yet it is considered to be anaerobic because instead of molecular O_2 inorganic oxides are used. Thus, the oxygen which accepts electrons (i.e. hydrogen) is a part of an inorganic compound and not free.

Some facultative anaerobes, which are ordinarily aerobic, can grow anaerobically if nitrate is present in the medium. For example, Aquaspirillum itersonii, an aquatic bacterium is dependent on O₂ unless potassium nitrate is added to the medium. In such cases, nitrate essentially substitutes the oxygen as final electron acceptor. The pathways for dissimilation of carbon and energy sources are identical with those in aerobic respiration and electron transport occurs via a respiratory chain similar to that of aerobic cells. Here, only the oxygen is replaced by nitrate which acts as the terminal

electron acceptor. However, in some obligate (strict) anaerobes, other compounds such as carbon dioxide or ions e.g. sulphate (SO_4^2) , thiosulphate $(S_2O_3^2)$, sulphite (SO_3^2) , etc. may also be used as the final electron acceptor.

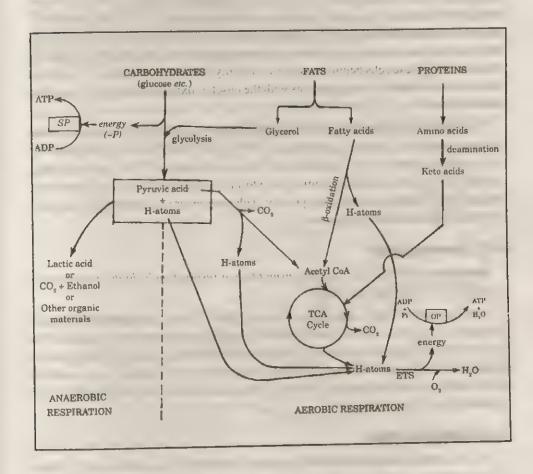


Fig. 9.9: Schematic representation of oxidation of carbohydrates, fats and proteins in cellular respiration.

[SP = Substrate level phosphorylation, OP = Oxidative phosphorylation]

9.16. Pasteur Effect

Definition: Decrease of glucose consumption due to inhibition of glycolysis in

presence of oxygen is called Pasteur effect.

Louis Pasteur discovered it during his important investigation of alcoholic fermentation process (i.e. formation of ethyl alcohol from glucose) in yeasts. Pasteur observed that yeast cells consumed glucose much more slowly in aerobic condition than in anaerobic condition. However, it is a general property of all facultative cells including those of higher animals.

A facultative cell e.g. yeast can utilise glucose in both anaerobic and aerobic conditions.

In such a cell, during anaerobic condition, only glycolysis (anaerobic) is operative and the yield of ATP per molecule of glucose is much smaller than that during aerobic condition in which both glycolysis and TCA cycle are operative. Under anaerobic condition, the cell would therefore carry out breakdown of glucose at a rate many times greater than that in aerobic condition in order to generate ATP at the same rate. If oxygen is admitted to anaerobically respiring facultative cells utilising glucose at a high rate by glycolysis, the rate of glucose consumption declines dramatically, because in presence of O₂ these cells begin to respire aerobically. This phenomenon, *i.e.* inhibition of glucose consumption and glycolysis with the onset of oxygen consumption is called Pasteur effect.

The Pasteur effect is due largely to feedback inhibition of some glycolytic enzymes by some product of aerobic respiration (i.e. TCA cycle) such as citire acid, NADH₂, ATP etc. Thus, there is a nice co-ordination between the rates of TCA cycle operating in mitochondria and glycolysis occurring in cytosol. The Pasteur effect in very important because by this mechanism, the total quantity of glucose undergoing oxidation is adjusted to fit the requirement of the tissues.

9.17. Crabtree Effect

Definition: Inhibition of oxygen consumption or respiration by high concentration of glucose is called Crabtree effect.

The Crabtree effect is opposite of Pasteur effect. It is a characteristic of tumor cells and several other normal tissues that exhibit a high rate of aerobic glycolysis. The Crabtree effect is possibly caused by delpletion of ADP and Pi due to a high rate of glycolysis (that occurs in presence of high concentration of glucose), as a result of which mitochondria are deprived of these compounds and aerobic respiration (i.e. O₂ consumption) is decreased.

9.18. Extinction Point

The facultative anaerobes continue to respire anaerobically in absence of O_2 . When O_2 is available, they start aerobic respiration and anaerobic respiration begins to decrease. If the O_2 supply is increased gradually, the rate of aerobic respiration will also increase gradually along with a proportional decrease in the rate of anaerobic respiration. In this way, at a certain concentration of O_2 , the anaerobic respiration will stop completely and only aerobic respiration will continue. The concentration of oxygen at which anaerobic respiration ceases and only aerobic respiration occurs, is called extinction point.

9.19. Photorespiration

Normally, respiration occurs in all living cells in both light and dark conditions (i.e. day and night) while photosynthesis occurs only in presence of light. In some plants, there is a special type of respiration that occurs in chorophyll containing cells in presence of light and results in evolution of excess CO₂. This type of increased respiration occurring in light was termed as photorespiration by Decker and Tio (1959).

Photorespiration occurs in C, plants in which Calvin cycle operates e.g. bean, beet, wheat, barely, rice, oat etc. Some tropical grasses such as maize, sugarcane etc. and some dicots like Amaranthus, Artiplex etc. lack photorespiration.

In photorespiration, glycolic acid (a 2-C compound) acts as the substrate which is derived from oxygenation of ribulose-1,5-biphosphate (RuBP). The glycolic acid is metabolised to release CO₂ through a complicated pathway. Photorespiration is accomplished by the joint action of **chloroplasts**, **peroxisomes** and **mitochondira**. It is stimulated by high O₂ concentration and low CO₂ concentration, and inhibited by high CO₂ concentration. In this process, H₂O₂ is formed and there is no oxidative phosphorylation (or ATP formation). Hence, it is supposed to be a wasteful process and it cannot be considered as true respiration because although it involves oxidation of substrate, it does not supply energy for a biological work. The proposed scheme of photorespiration is summarised in Fig. 9.10.

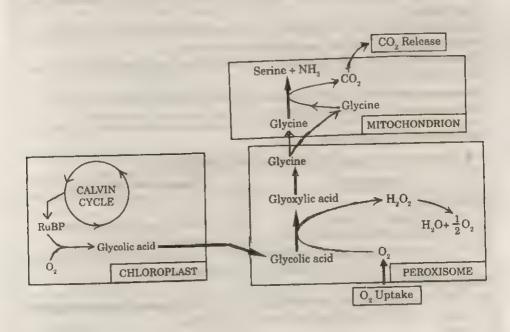


Fig. 9.10: Scheme of photorespiration.

9.20. Salt Respiration

This term refers to increase in respiration during salt (or ion) absorption by plants. It has been observed that when plants are transferred from water to saline medium (or salt solution), the absorption of salt is increased along with an increase in the rate of respiration. This increase in respiration over the normal respiration is termed as salt respiration. It is thought to be due to the increased demand of energy (ATP) supply for active absorption of salts by the plant.

REVISION

Fermentation-Anacrobic respiration of microbes occurring without the involvement of ETS. mateday set

Alcoholic fermentation-Fermentation of sugars to ethyl alcohol and CO,

Zymase-The enzyme (actually a mixture of enzymes) responsible for alcoholic fermentationing pres commencer or any expelience of the notice to open and both form

Homolactic fermentation-A fermentation process in which lactic acid is formed as the sole end product from anaerobic breakdown of sugars.

Heterolactic (or Mixed lactic) fermentation-A fermentation process in which along with lactic acid, other compounds are also produced as the end products, from anaerobic breakdown of sugars.

Pasteur effect-Inhibition of glycolysis in presence of O,

Crabtree effect-Inhibition of O, consumption by the presence of high concentration of glucose.

Extinction point-The concentration of O, at which anaerobic respiration is completely stopped and only aerobic respiration occurs.

Compensation point-The light intensity at which the rates of photosynthesis and respiration become equal.

Photorespiration—Increase in respiration of some plants in presence of light. Salt respiration-Increase in respiration of plants due to salt absorption.

9.21. A Few Comparisons

manner.

as heat.

atom of food.

[4] It is an enzyme regulated process. [5] Part of the energy released is stored

in ATP and the remaining is dissipated

combination of molecular O, with C

[6] During respiration, CO, is produced by decarboxylation and not by

A. • Comparison between Respiration and Combustion • Combustion (Burning) Respiration Similarities: [1] It is also an oxidative process. [1] It is an oxidative process. [2] It also releases energy. [2] It is associated with release of energy. [3] CO, and H₂O are usually produced [3] Combustion of a fuel also produces (when oxidation of food is complete). CO, and H,O. Differences: [1] It is a biological (or biochemical) [1] It is a chemical (non-biological) process which operates within living process. cells. [2] It requires high temperature. [2] It occurs at low temperature. [3] It is a rapid process in which [3] It is a slow process in which energy is

- released in a stepwise and controlled energy is released at a time in an uncontrolled manner.
 - [4] It does not involve enzymes.
 - [5] No energy is stored and it is entirely dissipated as heat and often light.
 - [6] CO, produced during combustion is formed by direct combination of molecular O, with the C atom of the fuel.

B. • Difference between Internal respiration (or Cellular respiration) and External respiration (or Breathing) •

Internal respiration (Cellular respiration)	External respiration (Breathing)				
[1] It is an intracellular process occurring in all living cells.	[1] It is not an intracellular process.				
[2] It involves the cytosol and a specialised organelle, the mitochondira.	[2] It involves specialised respiratory organs and the cell membrane.				
[3] It is a biochemical process accomplished by oxidation.	[3] It is a biophysical process accomplished by diffusion.				
[4] Enzymes are essentially required for it (i.e. it is an enzyme-regulated process).	[4] Enzymes are not essentially required for it (i.e. it is not an enzyme-regulated process.)				
[5] It is an ATP generating process.	[5] It is not an ATP generating process.				
[6] Gases are used (O ₂) and produced (CO ₂) in it.	[6] Gases (O ₂ and CO ₂) are simply exchanged in it.				

C. ● Difference between Glycolysis and Krebs cycle ●

Glycolysis	Krebs cycle
[1] It is a non-cyclic pathway.	[1] It is cyclic pathway.
[2] It occurs in cytosol.	[2] It occurs in mitochondria.
[3] It operates in absence as well as in presence of oxygen (i.e. both in anaerobic and in aerobic conditions).	[3] It operates only in presence of oxygen (i.e. in aerobic condition).
[4] It is the first phase of aerobic respiration.	[4] It is the second phase of aerobic respiration.
[5] The respiratory substrate is oxidised incompletely in this process.	[5] It is the pathway for complete oxidation of repiratory substrates.
[6] It is the pathway for oxidation of carbohydrates mainly.	[6] It is the final common pathway for oxidation of all the three types of foods, namely carbohydrates, fats and proteins.
[7] It generates less ATP.	[7] It generates more ATP.

D. • Difference between Photosynthesis and Respiration •

Photosynthesis	Respiration			
[1] Exhibited by plant cells only.	[1] Exhibited by all living cells.			
[2] Presence of light is essential, thus periodical and occurs during the day time only.	[2] Independent of light, thus continuous and occurs at both day and night.			
[3] Endergonic process in which solar energy is transformed into potential chemical energy.	[3] Exergonic process in which potential energy is transformed into kinetic energy.			
[4] Chlorophyll is essential; hence occurs in chloroplasts or chromatophores.	[4] Chlorophyll not required; occurs in cytosol and mitochondria.			
[5] Anabolic process in which food material (sugar) is synthesised.	[5] Catabolic process in which food materials are broken down.			
[6] Basically a reduction process.	[6] Basically an oxidation process.			
[7] Oxygen is produced.	[7] Oxygen is usually consumed (except in anaerobic respiration).			
[8] CO ₂ is consumed for carboxylation reactions.	[8] CO ₂ is produced from decarboxy- lation reactions.			
[9] Involves lysis of water.	[9] Involves formation of water.			
[10] Reaction :- $CO_2 + H_2O + \text{energy} \rightarrow \text{foodstuff} + O_2.$	[10] Reaction := Foodstuff + $O_2 \rightarrow CO_2 + H_2O + energy$.			

E. ● Difference between Oxidative phosphorylation and Photosynthetic phosphorylation ●

Oxidative phosphorylation	Photosynthetic phosphorylation			
 [1] It is related to respiration. [2] It is independent of light and occurs continuously (day and night). [3] It takes place in mitochondria and does not require any pigment. [4] It requires molecular O₂ as the final electron acceptor. [5] It involves formation of water. [6] It is of single type (non-cyclic only). 	 [1] It is related to photosynthesis. [2] It requires presence of light, hence it is periodic and occurs during day time only. [3] It takes place in chloroplasts and requires photosynthetic pigments. [4] It does not require molecular O₂; NADP is the final electron acceptor. [5] It involves lysis of water. [6] It is of two types - cyclic and noncyclic. 			

F. • Difference between Aerobic respiration and Anaerobic respiration (or Fermentation) •

Aerobic respiration	Anaerobic respiration (Fermentation)
[1] Molecular O₂ is used.[2] Occurs in most organisms.	 [1] Molecular O₂ is not used. [2] Occurs in some micro-organisms and occasionally in some higher cells.
[3] Mitochondrial enzymes are required (carried out jointly by the enzymes localised in cytosol and mitochondria).	[3] Mitochondrial enzymes are usually not required (carried out by cytosolic enzymes only).
[4] Food is completely degraded to CO ₂ and H ₂ O.	[4] Generally food is incompletely degraded, leaving organic compounds as end products.
[5] Energy stored in food is fully released (i.e., more energy is released).	[5] Energy stored in food is partly released (i.e. less energy is released).
[6] Involves TCA cycle and ETS.	[6] TCA cycle and ETS are not involved (except in some anaerobic bacteria).
[7] The final electron (or hydrogen) acceptor is free (molecular) O ₂ .	[7] The final electron acceptor is an organic compound of an inorganic oxide (i.e. bound oxygen).

G. Comparison between Anaerobic respiration and Fermentation

The processes of anaerobic respiration in higher plants or animals and fermentation in micro-organisms are basically similar. In both the processes, (i) food is oxidised incompletely so that the energy stored in it is partly released and organic matters are produced as end products; (ii) glycolysis serves as the main pathway; and (iii) TCA cycle, ETS and molecular O₂ are not used. For this reason, the terms fermentation and anaerobic respiration are often used as synonyms. But in strict sense, fermentation is simply a type of anaerobic respiration occurring in micro-organisms. There is another type of bacterial anaerobic respiration in which unlike fermentation, food is completely oxidised through TCA cycle and ETS using inorganic oxides as final hydrogen acceptors. However, the following are the major differences betweeen anaerobic respiration and fermentation.

Anaerobic respiration	Fermentation (or Alcoholic fermentation)			
[1] Occurs in micro-organisms as well as higher animals and plants.	[1] Occurs in micro-organisms only.			
[2] Usually takes place in absence of oxygen. [3] Can continue for a short time only.	[2] May take place in absence as well as presence of oxygen.[3] Can continue for relatively longer periods			
[4] May involve TCA cycle and ETS in some bacteria.[5] It is of no industrial use.	periods. [4] Never involves TCA cycle and ETS. [5] It is industrially useful.			

H. • Difference between True respiration and Photorespiration •

True respiration	Photorespiration				
 Occurs in all living cells. Occurs both in light and dark. Substrate used in usually carbohydrate (hexose sugar) or fat or protein. Cytosol and mitochondria are involved in it. H₂O₂ is not produced. Oxidative phosphorylation (ATP formation) occurs. It is a useful process. 	 [1] Occurs in chlorophyll containing cells of mainly C₃ plants. [2] Occurs only in light. [3] Substrate used is glycolic acid (a 2-C compound). [4] Peroxisomes, chloroplasts and mitochondria and involved in it. [5] H₂O₂ is produced. [6] Oxidative phosphorylation (ATP formation) absent. [7] It is a wasteful process. 				

9.22. Matters to Recollect

- Respiration is a process by which living cells derive their energy from oxidation of food.
- Respiration is an exergonic and catabolic process.
- In respiration, potential energy stored in food is converted to kinetic energy.
- During respiration, a part of the energy released is captured in the form of high energy phosphate bonds of ATP.
- ATP is called energy currency of a cell.
- Aerobic respiration requires molecular (free) O,.
- Anaerobic respiration does not require free O,.
- Each mole (gram mole) of glucose (i.e. 180g. of glucose) yields **686 kcal** when fully oxidised.
- Mitochondria are the respiratory organelles of a cell.
- Respiration takes place day and night throughout life.
- Glucose is the chief respiratory substrate.
- Breathing is external manifestation of respiration.
- Exchange of gases between an organism and its environment is called **external** respiration.
- Process of cellular oxidation of food is called internal respiration or cellular respiration.
- Breakdown of carbohydrates to pyruvic acid is called glycolysis or EMP pathway.
- Glycolysis takes place both in presence and absence of O2.
- The cellular site of glycolysis is cytosol.
- Citric acid cycle or Krebs' TCA cycle is the final common path for oxidation of carbohydrates, proteins and fats.

- Oxidation of H atoms (removed from substrates) by oxygen is called terminal respiration.
- Terminal respiration is carried out by electron transport system (ETS) or respiratory chain.
- TCA cycle and ETS occur in mitochondria.
- In complete oxidation of glucose during aerobic respiration, 38 moles of ATP are generated per mole of glucose.
- β-oxidation is the preliminary process of oxidation of fatty acids to acetyl CoA.
- Fermentation is a type of anaerobic respiration occurring in micro-organisms without the involvement of ETS.
- In some bacteria, the anaerobic respiration involves TCA cycle and ETS.
- The process of anaerobic respiration in higher animals and plants is basically same as fermentation.

9.23. Summary

Respiration is a catabolic (exergonic) process in which food is oxidised to release energy. It occurs in all living cells, day and night. The process of respiration is basically reverse of photosynthesis and divisible into two phases external respiration and internal respiration. External respiration means exchange of gases between the environment and the organism by the physical process of diffusion. Internal respiration is a biochemical process of oxidation of food within the cells; it is also called cellular (or tissue) respiration.

The process of internal (cellular) respiration is fundamentally similar in different living organisms. It may be of two types- aerobic and anaerobic. In aerobic respiration, molecular O, is used to oxidise the food completely into CO, and H,O, and the total energy stored in it (food) is released. It occurs through three stagesglycolysis, TCA cycle and terminal respiration. In glycolysis, carbohydrates are broken into pyruvic acid which is then completely degraded through TCA cycle to release CO, and H atoms. Finally, the H atoms are transferred to molecular O, through a system of several carriers called electron transport system (ETS) or respiratory chain to form H,O. Part of the energy released during respiration is captured in the high energy phosphate bond (~P) of ATP which is formed by phosphorylation of ADP. The process of ATP formation is of two types-substrate level phosphorylation and oxidative phosphorylation. In the former, ADP is directly phosphorylated by a high energy compound formed as an intermeadiate during catabolism of food. On the other hand, oxidative phosphorylation is linked with ETS. In aerobic oxidation of glucose, 686 kcal is released and 38 ATP are formed per mole of glucose.

In anaerobic respiration, usually food is incompletely degraded and molecular O₂ is not used. Organic matters are left as end products and energy release is partial. In most cases, glycolysis serves as the main pathway. TCA cycle and ETS are not involved, hence there is no oxidative phosphorylation. For each mole of glucose oxidised in this way, only 40–47 kcal is released and 2ATP are generated. This type of anaerobic respiration is called **fermentation** in case of micro-organisms.

Fermentation is applied in production of alcohol, vinegar, lactic acid *etc*. and baking. There is another type of anaerobic respiration found in some bacteria in which food is completely oxidised like that in aerobic respiration, but here instead of molecular O₂, an inorganic oxide (*i.e.* bound oxygen) is used as the final oxidant (*i.e.* electron acceptor).

In some plants, a special type of cellular oxidation occurs with evolution of CO₂ in chlorophyll containing cells in presence of light; this is called **photorespiration**.

9.24. Naming/Discovery/Discoverer

- [1] Lavoisier (1743-1794) showed similarities between combustion and respiration.
- [2] Louis Pasteur (1857) described alcoholic fermentation in yeasts.
- [3] Eduard Buchner (1897) first showed that the cell-free extracts of yeasts may cause alcoholic fermentation.
- [4] Otto Warburg (1923) discovered a method for measuring gaseous exchange in living tissue by manometry.
- [5] G. Hevesy (1923) discovered the technique of tracing a biochemical pathway by using isotopes.
- [6] K. Lohmann (1929) discovered ATP, the source of ready energy in living cells.
- [7] Hans Krebs (1937) discovered TCA cycle.
- [8] F. Lipmann (1947) discovered coenzyme-A, a key compound in cell metabolism.
- [9] Embden, Meyerhof and Parnas described the glycolytic pathway.
- [10] Knoop (1905) proposed β -oxidation of fatty acids.
- [11] Decker and Tio (1959) first used the term photorespiration.

9.25. Answers to Special Questions

[1] What is energy currency of a cell?

Ans. Adenosine triphosphate (ATP) is called energy currency of a cell because it is the readily available form of chemical energy present in all living cells. ATP contains high energy phosphate bond (~P) that provides a vital energy link between cellular respiration and various activities of a cell. During respiration, the ~P of ATP is formed for storing energy and when energy is needed for a biological work, the ~P is hydrolysed.

(a) How many high energy bond phosphates are there in 1 mol of ATP?

(b) How many mols of ATP are generated when 1 mol of glucose is completely oxidised through aerobic system?

[J.E.E. 1992]

Ans. (a) There are two high energy bond phosphates in 1 mol of ATP. The terminal and the next phosphate bonds of ATP moleculs are high energy bonds.

(b) When 1 mol of glucose is oxidised completely through glycolysis and Krebs cycle, 38 mols of ATP are generated.

[3] Why respiration is called controlled combustion?

Ans. Combustion is the process of burning or oxidation of fuel producing CO₂ and heat that occurs in an uncontrolled manner so that all the heat is released at a time.

Respiration is a similar process in which a food is oxidised in a living cell with

release of energy. But in respiration, the oxidation of food occurs in a stepwise manner controlled by the enzymes so that the energy is released slowly and a part of it is stored in the form of ATP, the remaining part being released as heat. This is why respiration is called controlled combustion.

[4] How are the terms 'breathing' and 'respiration' related ?

Ans. Breathing is the physical process of gaseous exchange between an organism and its environment in which the organism takes up O₂ and gives out CO₂ while respiration is the chemical process of oxidation of food in a cell for release of emergy. Breathing is simply the external manifestation of respiration.

[5] Define external and internal respiration.

Ans. The physical process by which the living organisms take up oxygen and eliminate carbon dioxide through their body surface or specialised respiratory organs is called *external respiration*. The biochemical process of oxidation of food that occurs within living cells for releasing energy is called *internal respiration*, or cellular (or tissue) respiration.

Ans. In humans, like other higher animals, the external respiration refers to exchange of respiratory gases (O₂ and CO₂) in the lungs between the atmospheric air entering into the lungs and the blood flowing though the alveolar capillaries. In this process, O₂ is absorbed by blood from inhaled air and CO₂ is expelled from blood to alveoli for being exhaled.

In the *internal respiration*, there is exchange of gases $(O_2 \text{ and } CO_2)$ between the blood and the tissues. In this process, the tissues absorb O_2 from the blood capillaries and give out CO_2 into them, The O_2 is used and the CO_2 is produced

in the tissues during oxidation of food.

[7] What do you mean by aerobic respiration and anaerobic respiration?

Ans. The process of cellular respiration in which food is oxidised completely to produce CO₂ and H₂O using atmospheric oxygen (i.e. molecular of free O₂) as the final oxidant and the total energy stored in the food is released, is called aerobic respiration.

The process of cellular respiration in which food is oxidised to release energy without participation of atmospheric free O_2 is called *anaerobic respiration*. Here an organic compound or an inorganic oxide is used as the final oxidant.

What are complete anaerobes and partial anerobes? [J.E.E. 1986]

Ans. Complete anaerobes are those organisms which respire anaerobically by fermentation and cannot tolerate the presence of free O₂. They are not only incapable of aerobic respiration but are killed in presence of O₂. They are also called strict anaerobes or obligate anaerobes.

Partial anaerobes are those organisms which can live in presence as well as in absence of free O_2 and they can respire both aerobically and anaerobically. They are also called facultative anaerobes.

[9] What are respiratory substrates?

Ans. The energy yeilding food matters namely carbohydrates, fats and proteins present in a cell are called respiratory substrates because they are used as the starting material in cellular respiration. Among these, glucose (a carbohydrate) is the chief (or most common) respiratory substrate.

[10] (a) What is respiration? (b) What is its cellular site?

or

- (a) What do you mean by respiration? (b) In which locations of cell does it occur?
- Ans. (a) Respiration is a process by which energy is released as a result of oxidation of food within living organisms. (b) Respiration occurs in cytosol (or cytoplasmic matrix) and mitochondria of the cells.
- [11] Which parts of the cell are involved in aerobic and anaerobic respiration?

 Ans. Aerobic respiration—cytosol plus mitochondria.

 Anaerobic respiration—cytosol only.
- [12] Give the equation showing the net reaction of aerobic respiration considering glucose as the substrate. $C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 686 \text{ kcal}$ (glucose)
- [13] Name the major phases (or processes) of aerobic cellular respiration.

 Ans. Aerobic cellular respiration involves three major processes—(i) Glycolysis,

 (ii) TCA cycle and (iii) Terminal respiration (or electron transport system).
- [14] What is glycolysis? [J.E.E. 1880; Tripura H.S. 1997]

 Ans. Glycolysis is the preliminary pathway of catabolism of carbohydrates in which a six carbon unit or hexose is oxidised and broken into two molecules of pyruvic acid.
- [15] Where does glycolysis occur? [J.E.E. 1994; Tripura H.S. 1997]

 Ans. Glycolysis occurs in the cytosol (or cytoplasmic matrix) of almost all living cells.
- [16] In which process and where does glycolysis take place?
 Ans. Glycolysis takes place in the cytosol of the cells during the process of cellular respiration (both anaerobic and aerobic).
- [17] (a) Why is glycolysis considered as an anaerobic process? (b) Does it occur in anaerobic condition only?
 Ans. (a) Glycolysis is considered as an anaerobic process because it does not

require the presence of atmospheric free O_2 and it can proceed even in absence of free O_2 when electron transport system is inoperative. (b) No, glycolysis can occur in both aerobic and anaerobic conditions.

- [18] In which part of the cell glucose is anaerobically oxidised? [J.E.E. 1995]

 Ans. Glucose is anaerobically oxidised in the cytosol (or soluble fraction of cytoplasm) of the cell.
- [19] (a) By which process energy is released within cytoplasm? (b) Give an equation for this process. (c) How the energy released in this process is utilised in the living organisms? [J.E.E. 1978]
 - Ans. (a) Energy is released within cytoplasm by the process of *glycolysis* in which hexose sugars are oxidised to two molecules of pyruvic acid.
 - (b) $C_6H_{12}O_6 + 2NAD + 2ADP + 2P_1 \rightarrow 2CH_3CO COOH + 2NADH_2 + 2ATP + 2H_2O$. (glucose) (pyruvic acid)
 - (c) The energy released in this process is partially captured in the terminal high energy phosphate bond (~P) of ATP. When energy is required for any biological

function of the living organisms, the terminal ~P is hydrolysed and the energy liberated from it is utilised.

- [20] What are the end products of glycolysis? [J.E.E. 1985, '94, '97] Ans. Pyruvic acid, NADH., ATP and H.O.
- [21] Write the significance of glycolysis.
 - Ans. (i) Glycolysis is the common primary pathway for oxidation of different carbohydrates in both aerobic and anaerobic respiration.
 - (ii) Glycolysis is very important for generation of ATP particularly in anaerobic conditionis when no other pathway can operate to meet the energy needs of the cell.
 - (iii) It may help in converstion of carbohydrate to fat and amino acid.
- [22] State the significance of glycolysis in respiration. [J.E.E. 1980]

 Ans. Mention points (i) and (ii) of the answer to Q.-21.
- [23] How many mols of ATP are gained when 1 mol of glucose is oxidised through glycolysis under (i) aerobic and (ii) anaerobic condition?

 Ans. (i) Under aerobic condition—8 mols of ATP/mol of glucose.
 - (ii) Under anaerobic condition—2 mols of ATP/mol of glucose.
- [24] How many mols of ATP are gained for oxidation of each glucose unit of glycogen through glycolysis under (i) aerobic and (ii) anaerobic conditions?

 Ans. (i) Under aerobic condition— 9 mols of ATP/glucose unit.
 - (ii) Under anaerobic condition-3 mols of ATP/glucose unit.
- [25] Write the full names of -(i) ATP [J.E.E. 1990, '98; Tripure H.S. 1997]; (ii) ADP [Tripura H.S. 1996]; (iii) AMP; (iv) GTP; (v) GDP; (vi) NAD; (vii) NADP [J.E.E. 1990, '98; Tripura H.S. 1997]; (viii) FAD; (ix) FMN; (x) EMP pathway [Tripura H.S. 1997]; (xi) TCA cycle [J.E.E. 1996]; (xii) Co-SH; (xiii) ETS; (xiv) Pl.

 Ans. (i) Adenosine triphosphate; (ii) Adenosine diphosphate; (iii) Adenosine
 - monophosphate; (iv) Guanosine triphosphate; (v) Guanosine diphosphate; (vi) Nicotinamide adenine dinucleotide; (vii) Nicotinamide adenine dinucleotide; (viii) Nicotinamide adenine dinucleotide phosphate; (viii) Flavin adenine dinucleotide; (ix) Flavin mononucleotide; (x) Embden-Meyerhof-Parnas pathway; (xi) Tricarboxylic acid cycle; (xii) Coenzyme-A; (xiii) Electron transport system; (xiv) Inorganic phosphate.
- [26] What is TCA cycle or Krebs cycle or citric acid cycle?

 Ans. The cyclic pathway through which acetyl CoA molecule is completely oxidised to produce CO₂ and H atoms is known as TCA (or Tricarboxylic acid) cycle or Krebs cycle or citric acid cycle.
- [27] Why is Krebs cycle called TCA cycle? [J.E.E. 1990, '94, '97] Ans. Krebs cycle is called TCA cycle or Tricarboxylic acid cycle because the products of the first three steps of this cycle are tricarboxylic acids *i.e.* acids containing three carboxyl (-COOH) groups, namely citric acid, cis-acontic acid and isocitric acid.
- [28] Why is TCA cycle called Krebs cycle and citric acid cycle?

 Ans. TCA cycle is called Krebs cycle after the name of the famous biochemist

 Sir Hans Krebs who first described it. This cycle is also called citric acid cycle

 because the product of its first step is citric acid.

Where does citric acid cycle take place? [29]

[J.E.E. 1987]

Where does Krebs cycle occur?

[J.E.E. 1994]

Ans. Krebs cycle (citric acid cycle) occurs in the mitochondrial matrix.

When does TCA cycle operate-in anaerobic condition, in aerobic condition 1301 or in both?

Ans. TCA cycle can operate only in aerobic condition when the O, supply is

adequate to run the electron transport system.

- (a) Where are the enzymes of glycolysis and TCA cycle located ? (b) Why [31] should the reaction of TCA cycle stop in absence of oxygen? (c) How many ATP molecules will be generated during complete oxidation of one molecule of fructose-1,6-bispnosphate? Ans. (a) The enzymes for glycolysis are located in the cytosol or cytoplusmic matrix and the enzymes for TCA cycle are located in the mitochondiral matrix. (b) In the TCA cycle, oxidation is carried out by removal of 2H atoms with the help of NAD and FAD that are reduced to NADH, and FADH,. The NADH, and FADH, are reoxidised to NAD and FAD through the electron transport system (ETS) in which the 2H atoms are transferred to O, forming H,O. The TCA cycle is essentially dependent on the ETS for regeneration and continuous supply of NAD and FAD. Thus, in absence of oxygen, as the ETS becomes inoperative, the regeneration of NAD and FAD is not possible and the TCA cycle stops immediately.
 - (c) 40 ATP molecules. Explain briefly-mature human erythrocytes cannot carry out the Krebs citric acid cycle.

 [J.E.E. 1994]

 Ans. The citric acid cycle occurs in mitochondria because the enzymes required [32] for this are located in the mitochondrial matrix. Since mature human erythrocytes are devoid of mitochondria, they cannot carry out citric acid cycle.
 - How may ATP molecules are produced from a glucose molecule during 1331 - (m. 120 a)c / 110 a . . . Krebs cycle? Ans. In Krebs cycle proper (i.e. beginning with acetyl CoA), strictly speaking 1ATP is produced by substrate level phosphorylation in succinyl thiokinase reaction. Since each glucose gives 2 acetyl CoA molecules, for each glucose molecule 2ATP are produced. It to all the state of the st Again if we take into account the production of ATP by oxidative phosphorylation

also, then for each glucose molecule 24 ATP molecules are produced (12 ATP per Krebs cycle).

How many ATP molecules are produced from a glucose molecule during [34] [J.E.E. 1994] the whole process of respiration?

Ans. In aerobic respiration:

Total number of ATP molecules produced = 40

Number of ATP molecules consumed = 2

 \therefore Net gain of ATP molecules = 40 - 2 = 38.

In anaerobic condition:

Total number of ATP molecules produced = 4

Number of ATP molecules consumed = 2

 \therefore Net gain of ATP molecules = 4 - 2 = 2

How many ATP molecules will be gained from oxidation of 1 molecule of 1351 pyruvic acid or acetyl CoA through the TCA cycle?

Ans. From pyruvic acid-15 ATP molecules. From acetyl CoA-12 ATP molecules.

How Krebs TCA cycle is related to the function of RBC? [36]

Ans. In TCA cycle, succinyl CoA is produced which is used in synthesis of hemoglobin, the respiratory pigment present in RBC. The hemoglobin in turn is responsible for carriage of O, in the body which is the chief function of RBC.

How many molecules of FADH,, NADH, and CO, are produced in TCA [37] cycle from oxidation of 1 molecule acetyl CoA?

FADH, '--- -1 molecule 4 3 molecules - 2 molecules NADH,

What are (i) respiratory chain and (ii) terminal respiration? [38]

Ans. (i) The series of enzymes and carriers including pyridinoproteins, flavoproteins and cytochromes responsible for transport of H atoms or electron (reducing equivalents) from a substrate to molecular O, in aerobic respiration is called respiratory chain. It is also called electron transport chain or cytochrome system.

(ii) Terminal respiration is the final phase of aerobic respiration in which reducing equivalents (H atoms or electrons) are transferred through the respiratory chain

to molecular O, to form H,O with production of ATP.

Where does the electron transport system occur? [39] Ans. The electron transport system occurs in the inner membrane (cristae) of mitochondria.

Name the components of electron transport system. 1401 Ans. Pyridinoproteins (NAD/NADH, and N. DP/NADPH,), Flavoproteins (FAD/ FADH, and FMN/FMNH,), Coenzyme Q and Cytochromes.

How many mols of ATP are generated from reoxidation of each mol of [41] NADH, and FADH, through the electron transport system?

From PADH₂ - 3 mols of ATP From PADH₂ 2 mols of ATP

What do you mean by (i) substrate level phosphorylation and (ii) oxidative [42] phosphorylation?

(i) Substrate level phosphorylation means formation of ATP by capturing Ans. energy directly from an energy-rich substrate without the involvement of electron transport system.

(ii) Oxidative phosphorylation means formation of ATP which is coupled

with biological oxidation in the electron transport system.

How is O, utilised in cellular respiration? [43] Ans. In cellular respiration, O2 is utilised in the final phase of aerobic respiration

(i.e. terminal respiration). Here O2 is used as the final oxidant in the electron transport system for oxidising the H atoms (removed from the substrates in glycolysis, TCA cycle etc.) to H,O by the action of the enzyme cytochrome oxidase.

How CO₂ is evolved during combustion and cellular respiration?

Ans. During combustion, CO₂ is evolved from oxidation of carbon atoms by molecular O₂. In cellular respiration, C atoms are not oxidised by molecular O₂ and CO₂ is evolved from decarboxylation reactions.

[45] (a) What do you mean by beta (β) oxidation of fatty acids? (b) What are its products? [J.E.E. 1987]

- Ans. (a) β-oxidation is the preliminary process of fatty acid oxidation in which fatty acids are oxidised at β-carbon so that the last two carbon atoms from the carboxyl end of the fatty acid are spilit off as acetyl CoA rendering the fatty acid shorter by a two carbon unit.
 - (b) Products of β-oxidation are acetyl CoA and fatty acid (or fatty acyl CoA) shorter by two carbon atoms.

[46] Where does β-oxidation occur within cells? Ans. β-oxidation occurs in the mitochondrial matrix.

When does β-oxidation occur-in aerobic condition or in anaerobic condition or in both? Justify your answer.

Ans. β-oxidation occurs in aerobic condition (i.e. in presence of free O₂) only, which the electron transport system for which

because it is intimately linked with the electron transport system for which presence of O_2 is essential.

[48] Give two examples of each of the following that respire anaerobically—
(i) micro-organisms, (ii) higher plant cells, (ii) higher animal cells.

Ans. (i) Yeast (a fungus), Monocystis (a parasitic protozoan).

(ii) Cells of germinating seeds, Cells of potato tubers.

(iii) Skeletal muscle cells, Mature human red blood cells.

[49] What are putrefaction and fermentation? [J.E.E. 1995]

Ans. The term putrefaction refers to decomposition of organic materials, especially anaerobic splitting of proteins, by micro-organisms resulting in formation of incompletely oxidised compounds with foul smell.

The term *fermentation* refers to anaerobic respiration of micro-organisms in which an organic compound is the final oxidant. In this process, usually sugars are incompletely broken down to organic compounds e.g. ethanol, lactic acid or other organic acids etc. often with production of heat and waste gases.

[50] (a) Name the major types of fermentation. (b) Which biochemical pathway is common to both aerobic and anaerobic respiration? or Which biochemical pathway is common to all types of fermentations?

Ans. (a) Alcoholic fermentation and lactic acid fermentation.

(b) Glycolysis or EMP pathway.

[51] What are meant by (a) Pasteur effect and (b) Pasteurization?

Ans. (a) Pasteur effect-The phenomenon of decrease of glucose breakdown due to inhibition of glycolysis in presence of oxygen is called Pasteur effect after the name of Louis Pasteur who discovered it.

(b) Pasteurization-Pasteurization is a process in which milk is heated at a particular temperature for a fixed period of time to destroy the pathogenic bacteria that may be present in the milk while causing minimal changes in the composition, taste and nutritive value. There are different methods of pasteurization in which the range of temperature and the duration of heat exposure vary widely.

- What are homolactic fermentation and heterolactic fermentation? [52] Ans. Homolactic fermentation means the process of fermentation of sugars in which lactic acid is the sole end product. Heterolactic (or mixed lactic) fermentation is that type of fermentation of sugars in which lactic acid is produced along with other end products like ethanol, CO, and other organic compounds.
- How many ATP molecules are obtained from fermentation of 1 molecule [53] of glucose? Ans. 2 molecules of ATP.
- Why and how do the skeletal muscle cells and mature RBCs of man [54] respire anaerobically? Ans. The human skeletal muscle cells and RBCs respire anaerobically because they lack mitochondria in which aerobic respiration occurs. In these tissues, glucose is broken down by anaerobic glycolysis into two molecules of lactic acid.
- (a) What is yeast? (b) Living yeast cell are placed in dilute sugar solution [55] for some time. What are the possible changes that would take place in (i) sugar solution and in (ii) individual yeast cell? Ans. (a) Yeast is an unicellular fungus of class Ascomycetes which reproduces ascxually by budding or fission and sexually by conjugation. Physiologically, it is a facultative anaerobe, i.e. it can respire both anaerobically and aerobically.
 - (b) (i) Changes in the sugar solution:

Under anaerobic condition-The sugar will be fermented to ethyl alcohol and

Under aerobic condition-The sugar will be completely oxidised to CO, and H.O.

(ii) Changs in the yeast cell:

Under anaerobic condition-A few buds will be produced by the yeast cells. Under aerobic condition-Buds will be produced profusely by the yeast cell.

- Explain how photosynthesis and respiration are interrelated? Ans. Photosynthesis and respiration are essentially dependent on each other in [56] the following ways-
 - (i) Photosynthesis produces sugar and O2 that are used in respiration.
 - (ii) The energy stored in food during photosynthesis is released in respiration.
- Name one biochemical respiratory process occurring in each-cytosol and [57] mitochondria.

Ans. In cytosol-Glycolysis. In mitochondria TCA cycle or β-oxidation of fatty acids.

(a) When does photosynthesis and respiration occur? (b) What is the difference between photolysis and glycolysis? State your answer by [58] J.E.E. 1993 chemical equation.

Ans. (a) Photosynthesis occurs in day time only, whereas respiration occur day and night.

(b)	Respiration	Glycolysis
(i)	Photolysis is the integral process of	(i) Glycolysis is the first phase of
	photosynthesis requiring light and	respiration (both aerobic and
	chlorophyll but no enzyme.	anaerobic).
(ii)	Photolysis, as the name implies, is	(ii) Glycolysis, as the name implies, is the
(the light induced splitting of water	anaerobic breakdown of glucose into 2
	molecule.	molecules of pyruvic acid through
	Cunlight	several enzyme catalysed steps.
	H ₂ O Sunlight H' + OH	$C_8H_{12}O_6 + 2NAD + 2ADP + 2Pi \rightarrow$
1	Cnioropnyii	(glucosc)
		2CH,COCOOH+2NADH,+2ATP+2H,O
		(pyruvic acid)

- [59] (a) Why green plants should be removed from the patient's room at night?
 (b) Why we feel suffocation in a dense forest during night?
 - Ans. (a) At night, since photosynthesis is stopped, the green plants cannot purify the air by consuming CO_2 and producing O_2 , rather they consume O_2 and produce CO_2 due to respiration. Thus, the air becomes impurified by green plants at night. Moreover, if green plants are kept in the patients room they would compete for O_2 with the patient. This is why green plants should be removed from the patients room at night.
 - (b) In a dense forest at night, since the large number of plants continue to respire, there is a decrease of O₂ concentration and increase of CO₂ concentration, in the atmosphere. As this is not favourable for our respiration, we feel suffocation in such a situation.
- [60] What is photorespiration? [J.E.E. 1997]

 Ans. In most plants, generally respiration occurs at the same rate in light (day time) and in dark (night). But in some plants like paddy, tobacco, soyabean etc. the rate of respiration increases in presence of light. This light induced increased respiration is known as photorespiration.
- [61] What is salt respiration?

 Ans. The rate of respiration usually increases when a plant is transferred from water to salt solution. The amount by which the respiration is increased over normal is termed salt respiration.
- [62] (a) Why alcoholic fermentation can continue for a longer period than the anaerobic respiration of higher plant cells? (b) Why the wine becomes sour?
 - Ans. (a) In higher plant cells, the alcohol produced by anaerobic respiration is neither utilised nor excreted out and hence it is accumulated within the cell to produce toxic effects. This is why these cells cannot continue anaerobic respiration for a long time. On the other hand, in the yeast cells, the alcohol and CO₂ produced in fermentation are passed out of the cells so that they do not become toxic to the yeast cell and the fermentation can continue for a longer period.
 - (b) The wine becomes sour because the ethyl alcohol present in the wine is

fermented to acetic acid (acetic acid fermentation) by the action of the acetic acid bacteria e.g. Acetobactor aceti, Acetobacter xylinum etc.

(a) Write the full names of ATP and NADP. (b) How many energy bonds [63] are present in ATP? (c) Mention the amount of energy released when ATP is hydrolysed to ADP and inorganic phosphate. (d) Is the above reaction exergonic or endergonic in nature? (e) When do you find ATP formation [J.E.E. 1998] in plants?

Ans. (a) See answer to Q-25 (i) and (vii). (b) 2 bonds. (c) 7-8 kcal. (d) Exergonic.

(e) ATP formation in plants occurs in the following processes

(i) In the photochemical phase of photosynthesis, by photophosphorylation. (ii) In two steps of glycolysis by substrate level phosphorylation (iii) In one step of Krebs TCA cycle by substrate level phosphorylation (iv) In terminal respirationby oxidative phosphorylation.

Write a brief note on pyruvic acid. [64]

Ans. Pyruvic acid is a three carbon compound. It is a keto acid having formula -CH, COCOOH. In living cells, it forms a link between carbohydrate, protein and fat metabolism. It holds a key position in cellular respiration. It is formed from (i) breakdown of sugars through glycolysis, (ii) breakdown of glycerol portion of fat throught glycolysis and (iii) deamination or transamination of certain amino acids. Under aerobic condition, the pyruvic acid is further oxidised to acetyl CoA which then enters the TCA cycle for complete oxidation. Under anaerobic condition, it is either converted to lactic acid (in muscle cells, certain bacteria etc.) or tehyl alcohol (in yeast, higher plant cells etc.). In liver tissue, the pyruvic acid can be converted back to glucose during neoglucogenesis.

What is acetyl CoA? Ans. Acetyl CoA or acetyl coenzyme-A is a two carbon compound which is the [65] coenzyme derivative of acetic acid. It is also called active acetate or active two carbon fragment. It is written as CH -CO-S-CoA. It is formed from (i) oxidative decarboxylation of pyruvic acid and (ii) β-oxidation of fatty acids. It is oxidised in TCA cycle and used in various acetylation reactions, fatty acid synthesis and

formation of cholesterol, ketone body etc. (a) What are the end products of alcoholic fermentation? (b) Which [66] product is toxic to liver cell? Ans. (a) Ethyl alcohol (ethanol), CO2, H2O and ATP (b) Ethyl alcohol.

What are the end products of aerobic and anaerobic respiration?

[J.E.E. 2001] [67]

Ans. Aerobic respiration-CO2, H2O and energy (morc). Anaerobic respiration- Ethyl alcohol, lactic acid, CO2, H2O and energy (less).

EXERCISE - EXERCISE Essay type or Long Answer type : What is respiration? What is its cellular site? Differentiate external respiration and internal respiration. [1]

What do you mean by aerobic and anaerobic respiration 9 Describe briefly the process of aerobic

121 (Ans. 9.15 respiration. Describe the process of anaerobic respiration. [3]

What is glycolysis? In which process and where does it take place? What is formed as its result [4] Describe briefly the said process.

VO	
[5]	What is glycolysis? State its significance in respiration? [J.E.E. 1980] (Ans. 9.12.1) By which process energy is released within cytoplasm? Give an equation for this process. How the
[7]	energy released in this process is utilised in the living organisms." [J.E.E. 1978] (Ans. 9.25 Q-19) "During respiration potential energy is converted into kinetic energy." What is it meant by? (Ans. 9.1)
[8]	Describe the late of pyruvic acid in a living cell in aerobic condition. How many moles of ATP are formed when one mole of glucose is oxidised aerobically. What is the significance of ATP synthesis? [Tripura H.S. 1982] (Ans. 9.12)
191	"The process of aerobic respiration is just reverse of photosynthesis" justify the statement. [Tripura H.S. 1980] (Ans. 9.21.D)
[10] [11] [12] [13]	What do you mean by fermentation "Describe the process of alcoholic fermentation (Ans. 9.15) Describe the process of anaerobic respiration in higher animals and plants (Ans. 9.15) Describe the process of anaerobic glycolysis in skeletal muscles and mention its significance. The content of the process of anaerobic glycolysis in skeletal muscles and mention its significance.
[14] [15] [16]	How fats are oxidised in respiration? What do you mean by external respiration? What do you mean by respiration? In which locations of cell it occurs? Distinguish between external and internal respiration Describe briefly the process of glycolysis. (Aps. 9.1, 9.10, 9.21.B, 9.12.1)
[17]	Give a balance sheet of AIP production and utilisation during complete oxidation of glucose through glycolysis and TCA cycle. (Ans. 9.12.4.A)
[18] [19]	Describe the fate of pyravic acid during aerobic and anaerobic respiration (a) How energy is produced in the cytoplasm of a living cell? (b) Describe the chemical process of the system. (Ans. 9.12)
[20]	(a) Define external and internal respiration (b) Mention the types of respiration with definition in each case (c) Make differences between aerobic and anaerobic respiration. (Ans. 9.6, 9.9, 9.21.F)
[21]	(a) What is glycolysis '(b) Where does this process occur '(c) Describe briefly the glycolysis process. (Ans. 9.12.1)
{22}	(a) What is glycolysis? (b) In which part of the cell it occurs? (c) Mention the principal differences between acrobic and anaerobic respiration [Tripura H.S. 1997] (Ans. 9.12.1, 9.21.F)
[23]	(a) What is yeast? (b) Living yeast cells are placed in dilute sugar solution for some time. What are the possible changes that would take place in (i) sugar solution and in (ii) individual yeast cell? [J.E.E., 1991] (Ans. 9.25 Q-55)
[24]	(a) Where are the enzymes of glycolysis and TCA cycle located? (b) Why should the reactions of TCA cycle stop in absence of oxygen? (c) How many ATP molecules will be generated during complete
[25]	what is respiration? Distinguish between aerobic and anaerobic respiration. What is respiration? Distinguish between aerobic and anaerobic respiration. How many ATP molecules are generated due to complete oxidation of a glucose molecule during aerobic respiration? (Ans. 9.1, 9.21.F, 9.12.4A)
• B. S	hort answer type:
[1]	What is energy currency of a cell? (Ans. 9.2)
[2]	What are the end products of glycolysis? [J.E.E. 1985, '94, '97] (Ans. 9.12.1) What is glycolysis?
[3]	
[5]	Why is Krebs evele called TCA cycle? [J.E.E. 1990, '94, '97] (Ans. 9.12.2) Where does citric acid cycle take place? [J.E.E. 1987] (Ans. 9.12.2) or
	Where does Krebs cycle occur? [J.E.E. 1994] (Ans. 9.12.2)
[6]	What is the importance of Krebs TCA cycle? What do you understand by fermentation? (Ans. 9.12.2) (Ans. 9.15)
[7] [8]	Define anaerobic respiration. (Ans. 9.15)
[9]	What do you mean by β-oxidation of fatty acid " What is its product " [J.E.E. 1987] (Ans. 9.13)
[10]	What is homolactic and heterolactic fermentation? (Ans. 7.13)
[11]	What do you mean by alcoholic fermentation? Give an overall equation for it (Ans. 9.15) What is anaerobic glycolysis? Cive an overall equation for the process (Ans. 9.15)
[13]	What is terminal respiration? (Ans. 9.12.3)
[14]	What are complete anaerobes and partial anaerobes ' [J.E.E. 1986] (Ans. 9.9)
[15]	What are respiratory substrates? (Ans. 9.8)

	RESTRATION	, ,
[16]	When do photosynthesis and respiration occur? [J.1	.E. 1993] (Ans. 9.3)
[17]	Mention the cellular sites of glycolysis, TCA cycle and B oxidation (Ans.	9,12,1, 9,12,2, 9,13)
[18]	Why glycolysis is called EMP pathway?	(Ans. 9.12.1)
[19]	What do you mean by homotermentative and heterofermentative inicio org	anisms " (Ans. 9.15)
[20]	How much ATP is formed per mole of glacose during anaerobic respiration in	plants 1 (Ans. 9.15)
[21]	How many ATP are formed per molecule of NADH, and FADH, when the	se are oxidised through
	electron transport system ?	(Ans. 9.12.3)
[22]	Explain why sleeping under a tree at night is harmful	(Ans. 9.3)
[23]	Give two examples of each for animal and plant cells that can respire in abse	nce of O (Ans. 9.15)
[24]	How many high energy bond phosphates are there in 1 mole of ATP ' [J.E.	.F., 1992, 198 (Ans. 9.2)
[25]	How many moles of ATP are generated when I mol of glucose is comple	stely oxidised (through
1001	serobic system) ? [J.E.E.	[992] (Ans. 9.12.4A)
[26]	What is acetyl CoA ?	(Ans. 9,25 Q,-67)
[27]	(a) Where does placelysis occur? (b) What are the end products of glycolysis	" (c) Where does Krebs
1	and agent 2 (d) Why is it called ECA cycle 2 (e) How many AIP molecul	les are produced from a
	placese molecule during Krehs cycle ? (f) How many AIP molecules are p	roduced from a glucose
	pyslecule during the whole process or respiration? [J.F.E. 1994] (Ans.	9,12,1, 9,12,2, 9,12,4)
[28]	Write the full name of (a) ADP, (b) TCA cycle [Tripura H.S. 198	06] (Ans. 9,25 Q,-25)
[29]	Wester the full name of (a) NADP (b) EMP Pathway, (c) ATP	
11	(Tripura H.S. 19	97] (Ans. 9.25 Q-25)
1301	Where does citric acid cycle take place? [J.f.,f-	. 1987 (Ans. 9.12.2)
[31]	Give the full name of NADP and ATP J.F.E. 1990.	98) (Ans. 9,25 Q-25)
[32]	What is the difference between photolysis and glycolysis? State your answer	r by chemical equation
10.01	J.E.E. 199.	3 (ABE, Y.45 Q-58.0)
[33]		E.F. 1994] (Ans. 9.4)
[34]	Cambridge why mature human crythrocytes cannot carry out Krebs	cycle
10.4	{J,E.E. 15	1941 (Ans. 9.25 Q-52)
[35]	What are putrefaction and fermentation ' J.E.E. 19	195] (Ans. 9.25 Q-49)
[36]	J.F.E. 15	97] (Ans. 9.25 Q-60]
[37]	a sur a dea full assure of ATP and NADP (h) How many energy bond	is are present in AIP
[2.]	the amount of energy released when AIP is higholysed	to Via and minikanic
	wheenhote (d) is the above reaction exergonic of endergonic in nature	(6) MILELL CITO AOM 11110
	ATP formation in plants ? [J.E.E. 19	198) (VIII) 2.72 (-02)
[38]	What is extinction point?	(Ans. 9.18)
[39]	tro . hIt measuration)	(Ans. 9.20)
[40]	the and aradusts of alcoholic fermentation, Which product is	toxic to liver cells '
1	J.E. E. A	Ann Caust Arra Canal
[41]	What are the end products or aerobic and anaerobic respiration 9 [J.E.E. 1	(001] (Ans. 9.25 Q-07)
[42]	CTCA	(Ans. 9.12.2)
	Distinguish between: Respiration and combustion.	(Ans. 9.21.A)
[1]	1 townstanding	E. 1002] (Ans. 9.21.B)
[2]		(Ans. 9.21.B)
[3]	- · · · · · · · · · · · · · · · · · · ·	(Ans. 9.21.D)
[4]		
[5]	Acrobic respiration and anaeronic respirators [J.E.E. 2003 ; Tripura H.	S. 1997 (Ans. 9.21.F)
161	Chambers and Krohs cycle	(Ans. 9.21.C)
[6]		(Ans. 9.21E)
[7]		(Ans. 9.21.F)
[8]	A combination and fermentation	(Ans. 9.21,G)
[9]	defect the same than and alcoholy lermentation	E. 1986] (Ans. 9.21.G)
[10]		93] (Ans. 9.25 Q-58b)
[11]	rhototysts and grycert ar	(Ans. 9.21.H)
[12]		
• D.	Write brief notes on :	Fermentation (Ans. 9.15).
[1	Aerobic respiration (Ans. 9.11), [2] Anaerobic respiration (Ans. 9.15), [3]	5). 161 Giveolysis (Ans.
[4] He	Aerobic respiration (Ans. 9.11). [2] Attaction Costs are comparation (Ans. 9.15). [5] Alcoholic fermentation (Ans. 9.15). [5] Alcoholic fermentation (Ans. 9.15). [6] December 2015 (Ans. 9.25). [64]. [91]	erminal respiration (Ans.
9.12.1)). [7] Krebs cycle (Ans. 9.12.2). [8] Pyrusic acid (Ans. 9.25 Q-64]. [9] To [10] Electron transport system (or Respiratory chain) (Ans. 9.12.3). [11] Photores	asteur effect (Ans. 9,16).
9.12.3). [10] Electron transport system for Respiratory Chain (Aus. 5.12.5). [11] extinction point (Ans. 9.18). [13] Crabitee effect (Ans. 9.17). [14] Photores	piration (Ans. 9.19).
1121 C	xtinction point (Ans. 9.18). [13] Craotice effect (Ans. 2.17), [14] I follows	

[12] Extinction point (Ans. 9.18). [13] Crabtree effect (Ans. 9.17). [14] Photorespiration (Ans. 9.19).

E. Cor	mplete the sentences with suitable words:
[1]	Description is a process.
[2]	in the food within a cell is
131	
[4]	C ₆ H ₁₂ O ₆ + + + 080 KCal.
[5]	respiration takes place in presented $+$ 686 kcal. C ₆ H ₁₂ O ₆ + = 6CO ₂ + + 686 kcal. In anaerobic respiration, is produced in skeletal muscles.
[6]	cycle operates during respiration.
[7]	In glycolysis, one mole of is oxidised to produce
[8]	energy is stored in lood.
[9]	TCA cycle operates in of cells.
[10]	
[11]	and are produced in higher plants during and
[12]	Anaerobic respiration in yeast is also called
	Multiple choise type questions: Choose the correct answers from those given in
F.	
[1]	The energy released during respiration is captured in
[2]	The chief respiratory substrate is (glucose/proteins/lipids) The chief respiratory substrate is (glucose/proteins/lipids) (photolysis/elveolysis/Krebs cycle)
[3]	
[4]	Breakdown of glucose to pyrittle and is caned in aerobic condition, complete oxidation of 1 mole glucose through glycolysis and Kerbs cycle in aerobic condition, complete oxidation of 1 mole glucose through glycolysis and Kerbs cycle in aerobic condition, complete oxidation of 1 mole glucose through glycolysis and Kerbs cycle
[5]	
	- EATD - or mole of olucose diffine aliacionic kiyeoffold in
[6]	
[7]	
[8]	
[9]	The Krebs cycle operates in
1101	Glycolysis is also called pathway. (HMP/EMP/PPP)
[10]	
• G.	State whether the following statements are true or false:
[1]	ATP molecule contains three high energy phosphate bonds.
12	Respiration is an exergenic process.
3	Glycolysis takes part in aerobic respiration.
4	TCA cycle occurs in mitochondria.
5	Citric acid cycle takes part in oxidation of fats.
6	E-manufacture is a process of respiration.
[7	A looked may be produced in higher animals during anaeronic respiration.
8	The and product of angerobic glycolysis in muscle is pyruvic acid
9	Fach molecule of NADH, produces 3 molecules of ATP inrough £13.
[10	to the state level whosphosphotophotophotophotophotophotopho
	Answers to Q. Nos. E, F and G
	COLOR SERVICE
E.	[1] Catabolic. [2] Respiration, Oxidised. [3] Aerobic. [4] 6CO ₂ , 6H ₂ O [5] Lactic acid. [6] TCA,
	Acrobic. [7] Glucose, Two. [8] Potential [9] Millochondria [10] 36. [17]
	at the form and the second sec
F.	11) ATP 121 Mitochondrion, [3] Glucose, [4] Glycolysis, [5] 36, [6] 2, [7] Allacidote, [6] 25th
G.	aerobic and anaerobic. [9] Wittocholdria. [10] Ealse. [11] False. [2] True. [3] True. [4] True. [5] True. [6] True. [7] False. [8] False. [9] True. [10] False

Social Physiology

Topics Discussed: Balanced diet, Malnutrition (PCM, Iron and Iodine deficiency), Population problem and its control, in vitro fertilization, Sexually transmitted diseases (Syphilis, Gonorrhea, AIDS, Hepatitis B); Polio immunization, Anniocentesis, inequality of sexes, Lemale feticide

10.1. Balanced Diet

• What is balanced diet ?

A diet containing all the nutrients in adequate quantities and correct proportions to meet the nutritional requirements for maintaining good health of an individual is —called balanced diet.

A balanced diet supplies the calorie requirements and maintains growth and proper functioning of tissues so as to keep the individual healthy and free from nutritional disorders. A balanced diet should contain correct amounts of the following three kinds of foods:

- [1] Energy yielding foods i.e., foods rich in carbohydrates or fats e.g., cereals, roots and tubers, dried fruits, sugar and jaggery, butter, ghee and edible oils.
- [2] Body building foods i.e., protein rich foods e.g., milk, egg, fish, meat, pulses, nuts, soyabean etc.
- [3] Protective foods i.e., foods rich in vitamins and minerals e.g., vegetables, fruits, milk, liver etc.

The nutritional requirements and hence the composition of balanced diets differ depending on age, sex, physical activity, climatic condition and physiological or pathological state of the individual e.g., pregnancy, lactation, diabetes, obesity etc. Economic status, religion, customs and taboos and food habit of the individual should also be considered for selection of foodstuffs to be included in the diet. For an individual, balanced diets of varying costs can be formulated. In high cost balanced diet charts, larger amounts of milk and other costly animal foods (e.g., meat, fish etc.) are included. In order to reduce the cost of balanced diet, milk, fish and meat can be replaced by egg, pulses, legumes, nuts etc. Cheaper fruits like papaya, guava, tomato or banana may be used in place of costly ones (apple, grapes, dry fuits).

• Balanced diet for infants :

In case of humans, a baby upto 12 months (1 year) of age is said to be an infant. Mother's milk is the most ideal food for infants during the early months. The number of breast feeding per day varies with the age of the baby. A normal infant should be breast feed 7 times / day during the 1st month, 6 times / day during 2-7 months of age and 5 times/day during 8 12 months of age. However, a strict feeding schedule

is not necessary and an infant may be put to breast on demand. When breast feeding is not possible (e.g., when the mother has to go out for working or she is suffering from infectious diseases or she is lacking breast milk) the infant has to be fed artificially with cows milk. Cow's milk and human milk differ in composition. So, for feeding the infant, cow's milk is diluted with water, and sugar is added to it; this is called humanization of cow's milk (i.e., making the cow's milk equivalent to human milk in composition so that it can be easily digested by human infants). The infant is gradually habituated to less diluted cow's milk. Besides milk, an infant should be given fruit juice, vitamin D, cereals, cooked and mashed vegetables and fruits and egg yolk. The balanced diets for infants (1—12 months) are shown in table 10.1.

Table 10.1: Balanced diets for infants:

Table 10.1 : Balanced diets for infants .								
	Age (months)							
	1	2	3	4-5	6-7	8–9	10-11	12
Number of feeds/day	7	6	6	6	6	5	ometer 5	5
Cow's milk (ml)	400	500	600	700-750	800-850	900-950	900–950	1000
Water (ml)	300	300	300	300	200	100	100	
Cone sugar (g)	20	30	40	50	60	60	60	60
Vitamin D (I.U)	400	400	400	400	400	400	400	400
Fruit juice (ml)		-	10	15	20	25	30	35
Cereal food (g)		_		10	15	25	30	40
Egg yolk		-	_	_	1/2	1/2	1	1
Mashed vegetables and fruits (Teaspoons)		_	_		4	4	6	8

Balanced diet for growing children :

The term 'growing children' includes both pre-school children (age 1-6 years) and school children (age 7 12 years). Some moderate cost vegetarian and non-vegetarian balanced diets for growing children of different age groups ranging between 1-12 years are given in table 10.2.

• Balanced diet for students (school students) :

School students are usually of the age group 7-18 years. Some moderate cost vegetarian and non-vegetarian balanced diets for school students (school children and adolescents) of different age groups are given in table 10.2.

Table 10.2: Moderate cost balanced diets for growing children (1-12 yrs) and school students (7-18 yrs). [V=Vegetarian; NV=Non-vegetarian]

						0								
				Growing children	children					W	Adolescents	Its		
	Dre	Pre-school Children	hildren			School Children	hildren			Boys	S		Girls	
50	1 2 Veare	Zoore /	4 6 Years	Sars	7—9 Years	Years	10-12 Years	Years	13—	-15 Years	16—	-18 Years	13-18	13-18 Years
(g day)		> > N	>	Z	>	3	>	ž	>	N.	>	Ž	>	7.
	. 001	120	170	170	220	220	290	290	400	400	420	420	320	320
Cereals	50	40	09	50	70	99	70	09	70	50	70	50	70	50
Green Leafy		0,4	75	75	75	75	100	100	100	100	100	001	150	150
vegetables Other vegetables,		000	C. C.	2 5	9	9	75	75	150	150	175	175	150	150
roots and tubers	30	30	00,	95	9	100	100	100	100	100	100	100	100	100
Fruits	138	201	201	no I	201		007	100	900	400	009	400	009	400
Milk	009	400	009	400	009	400	Ono	004		30	3	30	30	30
Fats and oils	20	20	25	25	30	30	30	30	9,	O.C.	3			
Meat, fish and eggs	1	40	1	50		99	1	09	,	80	1	08		08
Sugar and	30	30	40	40	30	30	30	30	30	30	30	30	30	30
Peanut		1	1		30	1	30	1	50	1	20		95	1
	-													

is not necessary and an infant may be put to breast on demand. When breast feeding is not possible (e.g., when the mother has to go out for working or she is suffering from infectious diseases or she is lacking breast milk) the infant has to be fed artificially with cows milk. Cow's milk and human milk differ in composition. So, for feeding the infant, cow's milk is diluted with water, and sugar is added to it; this is called **humanization of cow's milk** (i.e., making the cow's milk equivalent to human milk in composition so that it can be easily digested by human infants). The infant is gradually habituated to less diluted cow's milk. Besides milk, an infant should be given fruit juice, vitamin D, cereals, cooked and mashed vegetables and fruits and egg yolk. The balanced diets for infants (1 –12 months) are shown in table 10.1.

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Age (months)										
	1	2	1113	4-5	6–7	. 8-9	10–11	12		
Number of feeds/day	7	6	6	St 14. 6	6	- 15	√41 - 50 5 h	5		
Cow's milk (ml)	400	500	600	700-750.	800-850	900–950	900–950	1000		
Water (ml)	300	300	300	300	200	100	100			
Cane sugar (g)	20	30	40	50	60	60	60	60		
Vitamin D (I.U)	400	400	400	400	400	400	400	400		
Fruit juice (ml)			10	15	20	25	30	35		
Cereal food (g)	_	-	-	10	15	25	30	40		
Egg yolk	_	-	-		1/2	1/2	1	1		
Mashed vegetables and fruits (Teaspoons)	_	_	_	_	4	4	6	8		

Balanced diet for growing children :

The term 'growing children' includes both pre-school children (age 1-6 years) and school children (age 7-12 years). Some moderate cost vegetarian and non-vegetarian balanced diets for growing children of different age groups ranging between 1–12 years are given in table 10.2.

Balanced diet for students (school students) :

School students are usually of the age group 7-18 years. Some moderate cost vegetarian and non-vegetarian balanced diets for school students (school children and adolescents) of different age groups are given in table 10.2.

Table 10.2: Moderate cost balanced diets for growing children (1-12 yrs) and school students (7-18 yrs). [V=Vegetarian; NV=Non-vegetarian]

Balanced diet for pregnant woman:

During pregnancy, a woman requires extra nutrients to support growth and development of the baby in her womb. Vegetarian and non-vegetarian balanced diets of moderate cost for a pregnant woman doing sedentary work are given in table 10.3.

• Balanced diet for aged persons :

In aged persons, the caloric requirement is usually reduced due to their sedentary habits but the requirements for protein, vitamins and minerals are not reduced. Old people require adequate dietary fibres for bowel motility. They should be given adequate milk and fruits. Balanced diets of moderate cost for males and females over 50 years doing sedentary work are given in table 10.3.

Table—10.3 : Moderate cost balanced diets for pregnant woman and aged persons [V=Vegetarian ; NV=Non-vegetarian]

Foodstuffs (g/day)				person over 60 years edentary work)		
			Ma	ale	Fen	nale
	V	NV	V	NV	V	NV
Cereals	260	250	320	320	220	220
Pulses	80	50	70	55	60	45
Green leafy vegetables	100	100	100	100	125	125
Other vegetables	75	75	75	75	75	75
Roots and tubers	50	50	75	75	50	50
Fruits	110	110	75	75	75	75
Milk	800	450	600	400	600	400
Fats and oils	30	35	30	30	30	30
Meat and fish		85		60		60
Egg		30		30		30
Sugar and jaggery	30	30	30	30	30	30
Multivitamin-mineral tablet			1	1	1	1

10.2. Malnutrition

Impairment of health resulting from a deficiency, excess or imbalance of nutrients is referred to as malnutrition. It includes—(i) undernutrition due to deficiency of one or more nutrient(s) and (ii) overnutrition caused by excess intake of one or more nutrient(s) and usually calories. Vitamin deficiency diseases (e.g., beriberi, pellagra, scurvy etc.) and protein calorie malnutritions (e.g., marasmus and kwashiorkor) are the most important types of undernutrition. On the other hand, obesity (overweight) and hypervitaminosis are the best examples of overnutrition.

Nutritional deficiencies usually occur in the poor people. The most common nutritional deficiencies observed in our country are protein calorie malnutrition

among infantts and pre-school children, vitamin A deficiency (nyctalopia and blindness) among children, iron deficiency anaemia in all groups, iodine deficiency or endemic goitre, vitamin B-complex deficiency and others.

10.2.1. PROTEIN-CALORIF (OR PROTEIN-ENERGY) MALNUTRITION (PCM or PEM)

Earlier, the main cause of malnutrition among children was thought to be a deficiency of protein in diet. Subsequent studies have shown that the diets of these children are also deficient in calories (energy), certain vitamins and minerals. This type of nutritional deficiency is called protein-calorie malnutrition (PCM) or proteinenergy malnutrition (PEM).

• Definition: PCM (or PEM) can be defined as the nutritional deficiency disease due to inadequacy of protein and calorie along with some other nutrients in

the diet.

• Causes of PCM: PCM is basically due to inadequate food intake and / or defect in digestion, absorption or utilization of ingested food in the body. The causative factors responsible for PCM are as follows:-

[1] Poverty—The commonest cause of PCM is poverty or inability to pay for food. So, poor people and their children suffer from PCM due to inadequate food

intake.

- [2] Infections-Infections like diarrhea, measles, malaria. respiratory infections and intestinal worms increase requirements for calories, protein and other nutrients but decrease appetite as well as absorption and utilization of food, thereby causing malnutrition. Malnutrition lowers body immunity so that the victim is more vulnerable to infections. This sets up a vicious cycle : infection -> malnutrition -> infection.
- [3] Poor environmental conditions-Unhealthy and unhygienic environment with poor sanitation is responsible for frequent infections and thereby PCM.
- [4] Poor maternal health—It is associated with birth of low weight babies with poor nutritional reserve. Malnourished mothers with ill health usually show poor (or failure of) lactation so that their babies are deprived of breast milk. Moreover, mothers suffering from infectious diseases usually do not breast feed their babies. So, babies of unhealthy mothers are more vulnerable to PCM.

[5] Repeated pregnancies and large families—Repeated pregnancies adversely affect the nutritional status and health of the mother as well as her babies. In large families, children receive less attention, care and food which may lead to PCM.

[6] Faulty feeding practices—Premature termination of breast feeding and some faulty practices related to child rearing and weaning such as delayed supplementary feeding, use of over-diluted cow's milk and discarding cooking water from cereals may produce PCM.

[7] Unequal distribution of food in the family-In many families the available food is unequally distributed among the members. Share of women and pre-school

children is much less compared with economically active male adults.

• Types of PCM: PCM is of two major types— Marasmus and Kwashiorkor as described below.

MARASMUS

• Definition, cause and occurrence—Marasmus is the type of PCM caused by

a simultaneous deficiency of both protein and calorie. It is also known as the 'starvation disease of infants'.

It is seen most commonly in weaned infants of about one year (6–18 months) of age. It is usually observed in infants of poor parents when breast feeding is permanently replaced by less nutritive foods, low in proteins and calories. Due to the unhygienic lifestyle of the poor people, their infants often suffer from gastrointestinal infections and diarrhoea which impair absorption and aggravate marasmus.

• Symptoms—[1] Growth retardation (very severe); [2] Emaciation due to wasting



Fig. 10.1: A— A child suffering from marasmus showing emaciation. B— A child suffering from kwashiorkor showing oedema and skin lesions in legs and moon-face.

of muscles and subcutaneous fat (the skin becomes loose); [3] Signs of dehydration; [4] Skin-dry and atrophic; [5] Eye lesions (due to vitamin A deficiency); [6] Anaemia (may be present).

KWASHIORKOR

Definition, cause and occurrence—It is a nutritional deficiency disease caused by protein deficiency unaccompanied by calorie deficiency. It occurs most frequently in children older than one year (between 2-4 yrs) due to replacement of breast feeding by low-protein high-carbohydrate diets. The term 'kwashiorkor' was first introduced by Dr. Cicely Williams in 1935. She observed this disease in weaned infants of West Africa and discovered that the disease could be cured by feeding milk. The term 'kwashiorkor' means the disease which the child gets when the next baby is born i.e., sickness of deposed (weaned) child.

Symptoms—[1] Growth failure (less height and weight); [2] Muscle wasting; [3] Oedema and moon-face (rounded face); [4] Skin lesions (patches of hyperpigmentation, desquamation and ulceration of skin particularly in buttocks and legs); [5] Liver enlargement and fatty liver; [6] Gastrointestinal disorders (anorexia, vomiting and diarrhea); [7] Anaemia and vitamin deficiency diseases (due to impaired absorption of iron and vitamins); [8] Mental changes (the child lives an inert life and shows no interest in the surroundings).

• Remedy of PCM:

A child suffering from PCM should be given easily digestible, good quality proteins such as milk, curd etc., along with high calories and other nutrients in diet. Pulses should not be given because of their low digestibility. Calories may be provided through sugar, molasses, ripe fruits, honey etc. If there is any infection, it should be treated properly.

Prevention of PCM :

[1] Breast milk is not sufficient for a child older than six months. So, a child

should be provided with replacement diet from 5-6 months of age. The diet should contain high quality proteins, calories and other nutrients.

[2] Infectious diseases and epidemics are causative factors for PCM; so, measures

should be taken to prevent spreading of such diseases.

[3] Repeated pregnancy and high birth rates should be discouraged because these are deletorious for proper nutrition of both the mother and the child.

[4] Production of protein rich food e.g., soyabeans, legumes etc., should be increased so that they become available at low cost. Poultries, dairies, fisheries piggeries, etc., should be encouraged and developed to increase the supply of animal proteins.

[5] People should be educated about proper nutrition and health and also against

superstitions regarding food.

10.2.2. IRON DEFICIENCY

Deficiency of iron in the body produces a clinical condition called **anaemia** in which the haemoglobin (Hb) content of blood is lowered than normal. Iron is required for Hb synthesis and thus formation of RBCs. In iron deficiency, Hb production is reduced and the RBCs become smaller in size. This type of anaemia is called **hypochromic microcytic anaemia** (hypochromic = less coloured or low haemoglobin; microcytic = with smaller cells). Iron deficiency anaemia is a major malnutrition problem affecting all groups of population. It is found especially among children, women of child bearing age and pregnant woman.

Although nutritional anaemia is most commonly caused by iron deficiency, it may also be caused by deficiency of folic acid and vitamin B_{12} . But folic acid and vitamin B_{13} , deficiency produces a different kind of anaemia known as **megaloblastic (or macrocytic) anaemia** in which normal RBCs are replaced by large precursor cells called megaloblasts with less Hb.

• Causes of iron deficiency: Iron deficiency may occur due to three basic reasons: (i) inadequate intake, (ii) poor bioavailability (absorption) of dietary iron

and (iii) excessive loss of iron from the body.

Although most habitual diets contain fairly good amounts of iron, only a small amount (<5%) is absorbed. This poor bioavailability is the major cause of iron deficiency. Women lose a considerable amount of iron (due to blood loss) during menstruation and child birth. Pregnancy increases iron requirement. Mothers who have born children at close intervals become anaemic due to the additional demands of rapid pregnancies and the loss of blood in each delivery. Milk is a poor source of iron; so, infants lacking iron supplementation may suffer from iron deficiency anaemia. Anaemia may be caused or aggravated by diseasaes like malaria, hookworm infestation and piles.

- Adverse effects and symptoms (clinical features) of anaemia: Anaemia due to iron deficiency or any other reason shows the following ill effects (symptoms) low Hb content and hence decreased O₂ carrying capacity of blood, decreased work capacity, fatigue and lassitude, breathlessness on exertion, pallor of skin and mucous
- membrane etc.

 Treatment and prevention of iron deficiency anaemia: For treatment and prevention of anaemia, iron therapy (in the form of ferrous sulphate) is recommended usually along with folic acid. Attempts are being made to fortify common salt with iron to prevent nutritional deficiency of iron.

10.2.3. IODINE DEFICIENCY

lodine deficiency is another nutritional problem in India and neighbouring countries. It is characterized by **goitre** (swelling at neck due to enlargement of thyroid gland) along with less secretion of thyroid hormones (T_4 and T_3). Iodine is required for synthesis of T_4 and T_3 . So, in deficiency of iodine, production of T_4 and T_3 and thus the blood level of these hormones is lowered. This inturn stimulates the anterior pituitary in a feedback manner to secrete more TSH which causes enlargement of thyroid gland (goitre). It should be noted that iodine deficiency is the main but not the only cause of goitre. Iodine deficiency goitre is usually endemic in nature; hence, it is also referred to as **endemic goitre**.

- lodine deficiency disorders (IDD): Symptoms of iodine deficiency: lodine deficiency, is associated with goitre and hypofunction of thyroid gland producing cretinism in young ones and myxoedema in adults. These diseases are associated with various disorders (symptoms) that are collectively referred to as iodine deficiency disorders or IDD. Symptoms of cretinism and myxoedema have been described earlier in chapter-7 (Article 7.6).
- Causes and occurrence of IDD: Iodine deficiency is caused basically due to low iodine content in drinking water and food. So, IDD are usually endemic especially in hilly areas (far away from sea) where the soil, drinking water and food contain less iodine. In India, endemic goitre is prevalent in the Himalayan belt which is the world's biggest goitre belt. Some foods like cabbage, turnip etc., contain some antithyroid substances known as goitrogens which impair the utilization of iodine in the thyroid gland. Excessive consumption of these foods may cause or aggravate IDD.
- Control and prevention of IDD: For control and prevention of IDD, four methods have been used to increase iodine intake in goitre prone regions: (i) use of iodized salts (addition of iodide or iodate to common salt), (ii) addition of iodide or iodate to bread, (iii) use of iodized oil and (iv) use of iodine (potassium or sodium iodide) tablets. Among these iodized salt is most widely used because it is very easily available.

10.3. Population Problem And Its Control

- Population problem: It is the problem of overpopulation. For causes and adverse effects of population problem see vol-I, Appendix, Chapter-12, Long answer type questions -1 and 2.
 - Control of population problem : See Vol-1, Chapter-12 Art. No. 12.4.

10.4. In Vitro Fertilization

Infertility is a common problem among the couples. It refers to failure to achieve pregnancy after one year of trying. It may result from some defect in the reproductive function of either the husband of the wife. Many but not all cases of infertility can be corrected by surgical and/or drug treatments. Advancement of biotechnology has helped to develop certain methods for treatment of those cases of infertility where surgery and drug therapy fail to work. Such methods are collectively known as assisted reproductive technology or ART. In spite of its low success rate and high

expenses, ART has become popular nowadays. Availability of sperm and ovum banks (i.e., techniques for storage of sperm and ovum) and surrogate mothers have further helped the ART. The most common method of ART is in vitro fertilization and embryo transfer (IVF-ET) which is commonly known as 'test-tube baby' technique. Some other methods e.g., artificial insemination or intra-uterine insemination (IUI), gamete intra-fallopian transfer (GIFT), zygote intra-follopian transfer (ZIFT) and micro-insemination sperm transfer (MIST) are also available now.

• IVF-ET: Test-tube baby: A baby born by IVF-ET technique is termed as test-tube baby. The IVF-ET (or test-tube baby) technique was first devised by Patrick Steptoe and Robert Edwards in 1978. It is used in cases of (i) female infertility e.g., tubal disease (blockage or damage of fallopian tubes), cervical hostility (when the cervical environment interferes with viability of sperms and fertilization), endometriosis (when the lining of uterus or endometrium breaks away and grows else where), and failure of ovulation; (ii) male infertility e.g., oligospermia (low sperm count), abnormal sperms, impotence (inability to achieve or maintain erection of penis for coitus), premature ejaculation and absence of ejaculation; (iii) production of antibodies against sperm by the male or female and (iv) unexplained infertility (where the cause of infertility cannot be detected).

The technique involves collection of eggs (ova) from the ovary, fertilizing them in vitro (i.e., outside the body, in a laboratory setting), and then transferring the fertilized eggs known as pre-embryos back into the uterus. The main steps of IVF-ET are described below in brief:—

- [1] Stimulation of ovaries and monitoring of follicular growth: The ovaries are stimulated with fertility drugs (Clomphene and combination of gonadotrophins) to induce superovulation (production and release of several eggs in one cycle), thereby increasing the chances of successful egg collection and pregnancy. It also helps to improve the quality of eggs and to control the timing of ovulation. Growth of follicles is monitered by sonographic measurement of the number and size of the follicles. Blood tests for estrogen help to judge and control the timing of ovulation.
- [2] Retrieval (collection) and culture of eggs: Eggs can be collected from the follicles by laparoscopy. The laparoscope is a small telescope which is inserted into the abdomen through the navel for veiwing inside the body. Eggs are collected by sucking out the fluid contents of mature follicles with a fine hollow needle, also inserted through the abdominal wall. This is done under general anesthesia. Nowadays, the technique of ultrasound guided egg retrieval through vaginal route is preferred because it is simple, less damaging and can be performed without anesthesia using analgesics only. The sucked fluid is immediately examined with a microscope for presence of eggs. 5–15 eggs are usually collected. The eggs are placed in a special culture medium and maintained at body temperature in an incubator for a few hours to make them mature and suitable for fertilization.
- [3] Fertilization of eggs (in vitro) and culture of pre-embryos: Sperms are collected from the semen ejaculated by the husband (or a donor) and washed in a culture fluid to remove the seminal fluid. About 50,000 to 100,000 healthy (motile) sperms are added to each egg taken in a petri-dish with the culture medium, within 3 hours after egg collection. Successful fertilization is indicated by presence of two pronuclei and a second polar body in the egg, usually after 12-24 hours of

insemination. The fertilized eggs are further incubated in the culture medium and allowed to grow for 2 days within which they become 4–8 cell stage pre-embryos. The fertilization and growth of pre-embryos are examined with a microscope.

[4] Embryo transfer: 4-8 cell stage pre-embryos, taken in a drop of culture fluid are transferred into the uterine cavity through the cervix using a fine flexible plastic tube. A syringe gently squirts the fluid into the uterus. Pregnancy test is usually performed 14 days after the procedure. Larger the number of pre-embryos transferred, greater the chance of success, but this has to be balanced against the need to avoid multiple pregnancies. Usually three pre-embryos are transferred per cycle to have optimum success. Spare pre-embryos can be frozen and stored for further attempts if necessary. When the pregnancy test gives positive result (i.e., if pregnancy is achieved), proper hormonal support may be given by administering progesterone to maintain pregnancy. The lady bears the child in her womb under proper medical care and gives birth to the baby after completing the period of gestation. Although a baby born in this way is termed as 'test tube baby', it must be remembered that in this technique, the baby is not reared in a test tube; hence the term 'test-tube baby' is not proper. IVF-ET can be performed using (i) wife's ovum and husband's sperm or (ii) wife's ovum and donor's sperm or (iii) donor's ovum and husband's sperm or (iv) donor's ovum and donor's sperm.

Disadvantages of 'test-tube baby' (or IVF-ET) technique:

- [1] The success rate of IVF-ET is low (only 25% if 3 embryos are transferred per cycle). The rate declines with increase in age of the female.
- [2] The procedure is very expensive, specially because several attempts are usually needed.
- [3] There is a possibility of multiple pregnancy which increases the risk of miscarriage and perinatal mortality.
- [4] It also increases the risk of ectopic pregnancy (i.e., implantation of embryo outside the uterine cavity, e.g., in fallopian tube).
- [5] Stimulation of ovaries and superovulation in repeated attempts may cause ovarian cancer and premature menopause.
 - [6] It may have some ethical and psychological impacts.

• Other methods of ART:

- ▲ Intra-uterine insemination (IUI): In this method semen (or preferably motile fraction of sperm isolated from semen) is injected directly into the uterus by introducing a flexible tube through vagina. It is done at the time of ovulation, and a monthly schedule of 2 insemination on alternate days is preferred. The semen may be obtained from the husband (this is known as artificial insemination husband or AIH) or a donor (this is known as artificial insemination donor or AID). AIH is used in cases of impotency or premature ejaculation of the husband while AID is used when the husband is infertile or has a very low sperm count.
- ▲ Gamete intra-fallopian transfer (GIFT): It is a variation of IVF. In this method, both sperm and eggs are transferred into the fallopian tubes so that fertilization takes place in vivo (i.e., within the woman's body) and the pre-embryos move down to uterus where they may implant.
- ▲ Zygote intra-fallopian transfer (ZIFT): In this, the embryos (zygotes) are transferred into the fallopian tube rather than gametes as in GIFT. It is a better

alternative of GIFT and IVF. The advantage over GIFT is that fertilization can be confirmed. The advantage over IVF is that the pre-embryos enter the uterus naturally by way of the fallopian tube.

▲ Micro-insemination sperm transfer (MIST): It is a newly developing technique of IVF in which a few sperms are introduced directly in the perivitelline space of the egg using a very fine needle while viewing under a microscope. It is also called subzonal insemination (or SUZI) because the sperm is placed below the zona pellucida.

10.5. Sexually Transmitted Diseases

Sexually transmitted diseases (STD) are a group of communicable (or contagious) diseases that are transmitted predominantly by sexual contact from an infected partner. Such diseases were earlier called **venereal diseases** (VD; venery = sexual intercourse). STDs are caused by a wide range of bacterial, viral, protozoal and fungal agents and ectoparasites. Important examples of STDs are syphilis, gonorrhea, AIDS, hepatitis—B etc. Some STDs may be transmitted from an infected pregnant woman to her baby through placenta (syphilis, AIDS) or during passage of the baby through the birth canal (gonorrhea). Transfusion of infected blood or use of infected needles may also cause spread of such diseases (AIDS, syphilis, hepatitis-B). Important preventive measures against spread of STDs are—(1) use of condom during sexual intercourse, (ii) avoiding sexual relationship with prostitutes and (iii) avoiding sharing of injection needles, razors, blades etc.

10.5.1. SYPHILIS

Syphilis is a chronic sexually transmitted disease caused by the spirochaete (corkscrew shaped bacterium) Treponema pallidum.

- Modes of transmission: The causative bacteria producing syphilis usually enter the body during sexual intercourse, through the mucous membranes of vagina or urethra. They may rarely be transmitted through wounds in the skin or scratches. The bacteria may also pass from an infected pregnant woman across the placenta to the developing fetus so that the baby is born with the disease; this is called congenital syphilis.
- Signs and symptoms: Syphilis produces widespread lesions in the body tissues. The primary stage symptom appearing 2-4 weeks after infection is formation of hard, painless ulcers (chancres) at the site of infection or at any other part of the body e.g., vagina, penis, lips, fingers, nipples etc. Secondary stage symptoms appear about 2 months after infection and include fever, malaise, enlargement of lymph nodes and red skin-rashes. At primary and secondary stages, the patient is highly infectious. In untreated cases, the disease enters its tertiary stage after months or even years when the patient is non-infectious. This stage is associated with widespread. formation of tumor-like masses (gummas) and may cause serious damage to heart and blood vessels (cardiovascular syphilis), or to brain and spinal cord (neurosyphilis) resulting in blindness, insanity, paralysis and even death.
- Treatment: Syphilis can be cured by treatment with antibiotics like penicillin, tetracycline, crythromycin and doxycycline at an early stage of the disease.

10.5.2. GONORRHEA [Also spelt as gonorrhoea]

Gonorrhea is a sexually transmitted disease caused by the bacterium Neisseria gonorrhoeae which is a Gram negative coccus (spherical bacteria) and hence commonly called gonococcus.

- Modes of transmission: The gonococcus usually invades the body through mucous membranes during sexual contact with an infected partner or during delivery of a baby through birth canal of an infected woman.
- Signs and symptoms: Gonorrhea affects mainly the mucous membranes of urinogenital tract. Symptoms develop about a week after infection and include pain on passing urine (dysuria) and discharge of pus (known as gleet) from penis (in men) or vagina (in women). However, many infected women do not experience such symptoms. In untreated cases, the infection may spread throughout the reproductive system causing sterility. Other complications include fever, headache, arthritis, inflammation of heart valves (endocarditis) and infection of eyes (conjunctivitis).
- Treatment: Gonorrhea is usually treated with antibiotics like penicillin, streptomycin, ampicillin etc. Modern antibiotics like ciprofloxacin, ofloxacin, or cefotaxime are more effective.

10.5.3. AIDS

AIDS or Acquired Immune Deficiency Syndrome is a fatal illness caused by a

virus called human immuno-deficiency virus (HIV) which damages the human body's immune system, leaving the victim susceptible to various secondary infections and life threatening diseases. The term AIDS was coined by 'Centre for Disease Control' (CDC), Atlanta, USA in 1982. The causative agent of AIDS i.e., HIV was discovered in 1983 by Barre-Sinouss in Paris.

HIV is a RNA virus (retrovirus) capable of reverse transcription (making DNA from RNA) in the host cell. When a man is infected with HIV, the virus enters into blood and attacks

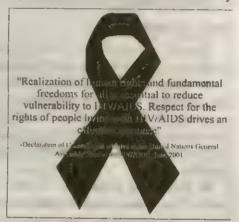


Fig. 10.2 · The Anti AIDS symbol and the UN declaration against AIDS

certain white blood cells (lymphocytes) that are responsible for the body's immune response. The virus multiplies within the lymphocytes, impairs their function and ultimately kills them. As a result of this, the immune system of the body is destroyed and the person is easily attacked by other diseases which may cause death of the victim.

● Modes of transmission: The HIV can only survive in body fluids. It is found in greatests concentration in blood, semen and CSF. Lower concentrations have been detected in saliva, tears, breast milk, urine and vaginal secretions, However, the virus is transmitted by blood and semen only. HIV may be transmitted from one person to another in the following ways:—

[1] Sexual contact: Intimate sexual contact with a HIV infected (i.e., HIV positive) partner is the main cause of spread of AIDS. So AIDS is included in the group of STDs. Vaginal, anal or oral sex can spread AIDS. Thus, both heterosexuals and homosexuals can acquire HIV from an infected sex partner. The risk of transmission is greater when the skin or mucous membrane is torn or damaged. Anal intercourse is of higher risk because it is more likely to injure the tissues of the receptive partner. For vaginal sex, the risk is greater when the woman is menstruating. Prostitution or having multiple sex partners is an important cause of spread of AIDS in human society.

121 Blood contact: AIDS may be transmitted by transfusion of HIV infected blood or blood products. Patients requiring frequent transfusion of blood or blood products are at higher risk of getting infected with HIV. Close contact between infected and non-infected people through cuts and open wounds may also pass on the

virus.

[3] Sharing of infected skin-piercing instruments: Use of syringe, needle or any other skin-piercing instrument (e.g., those used in ear-piercing, tattooing, acupuncture etc.) and even shaving razor or blade which has been used on a HIV infected person may transmit AIDS. Particularly the drug addicts who usually share syringe and needle for self injection are always at risk of getting infected with HIV.

[4] From mother to baby: A HIV positive mother can pass on the virus to her

baby through placenta during delivery or through breast-milk.

HIV is a fragile virus and it does not survive well outside the body in open air. It is not transmitted through mosquitoes or any other insects. Casual social contact with HIV positive persons e.g., kissing, shaking hands, touching of household articles used by an infected person and sharing of bathrooms, urinals, swimming pools, clothes, food, water etc., involves no risk of infection.

• Signs and symptoms: The incubation period of HIV (i.e., the period from HIV infection to development of AIDS or appearance of symptoms of the disease)

is uncertain and it may vary from a few months to 6 years or even more.

The virus can remain silent in the body for many years. So infection with HIV does not necessarily result in AIDS immediately. Most of the HIV positive persons remain symptomless and healthy for several years but they can transmit the virus to others; so they are called 'carriers'. AIDS is the last stage of HIV infection. Common symptoms of AIDS are—(1) Swollen lymph glands especially in neck and armpits, (2) Intermittent fever, (3) Unexpected weight loss (hence AIDS is also called 'slim disease'), (4) Profound fatigue, (5) Night sweats, (6) Frequent diarrhea, (7) Shortness of breath and persistent dry cough, (8) Skin and oropharygeal infections. Finally, an AIDS patient may develop a number of fatal opportunistic infections (e.g., pneumonia, tuberculosis, encephalitis, meningitis etc.) and unusual cancers (e.g., Kaposi's sarcoma) leading to death.

• Prevention: Till now there is no medicine (antibiotic etc.) to cure AIDS and no vaccine to protect people from the disease. So, utmost precautionary measures should be taken to prevent spread of this dreadful disease. These are as follows:-

[1] Restriction of sex: Restriction to one sexual partner reduces the risk of getting HIV infection. 'Free sex' in western countries has caused extensive spread of AIDS; so, it should be discouraged. Sexual contact with prostitutes should be avoided because they may act as HIV carriers.

- [2] Safer sex: Use of condom during intercourse prevents spread of AIDS as well as other STDs through sexual contact.
- [3] Restriction of sharing articles: Sharing of any device that punctures the skin should be avoided. Disposable syringe and needle are to be used for blood collection or injection. It is best not to use others shaving razors or blades and even tooth brushes (because in many people the gums may bleed when the brush their teeth). Surgical instruments should be properly sterilized before use.
- [4] Screening of blood: All blood and blood products should be screened for HIV before transfusion. HIV positive persons should refrain from donating blood. The blood of prostitutes should also be screened routinely to identify HIV positive carriers for proper rehabilitation.
- [5] Restriction and termination of pregnancy: HIV positive women should avoid pregnancy to prevent transmission of HIV to their babies. If such a woman becomes pregnant, pregnancy should be terminated.
- [6] Protection of health workers: Health care workers working with HIV positive persons should use gloves and avoid blood contact with the patient.
- [7] Education: People should be educated about the nature, transmission and prevention of AIDS. This is most important to develop mass awareness against spread of the disease. For this mass media should be involved. Educational materials and guidelines for prevention of the disease should be made widely available.
- Treatment: At present, there is no vaccine or cure for treatment of AIDS. Most treatments are limited to relieving the symptoms. However, some anti-retroviral drugs have been developed recently. They include reverse transcriptase inhibitors or protease inhibitors which suppress the HIV infection (i.e., replication of the virus in human body). Although these drugs neither restore the immune system nor kill the HIV, they can prolong the life of severely ill AIDS patients.

10.5.4. HEPATITIS-B

Hepatitis-B is a viral hepatitis (i.e., a viral infection causing inflammation and necrosis of liver) caused by hepatitis-B virus (HBV). The HBV was discovered by Blumberg in 1963. It is a DNA-virus which replicates in liver cells causing severe damage to liver. Hepatitis-B was formerly known as serum hepatitis.

Modes of transmission: Hepatitis-B is essentially a blood borne infection. It may spread in following ways: [1] By transfusion of infected blood or blood products; [2] Through dialysis; [3] Careless handling of infected blood; [4] Through contaminated syringes, needles, other skin-pricking instruments, razors and blades; [5] Accidental inoculation during surgical or dental procedures and acupuncture; [6] From infected mother to baby through placenta or during delivery (due to leak of maternal blood into the baby's circulation); [7] Through sexual intercourse with an infected partner; [8] By physical contact between infected and non-infected persons having cuts or wounds. Thus, drug-addicts, recipients of blood transfusion, doctors, health care and laboratory workers, homosexuals and prostitutes are at high risk of HBV infection.

- Signs and symptoms: Symptoms of hepatitis-B develop suddenly after an incubation period of 6 weeks to 6 months and include headache, fever, chills, general weakness, jaundice, nausea and severe loss of appetite. Most of the patients recover gradually but in some cases, the infection may become persistent and cause chronic hepatitis and even liver cancer leading to death.
- Prevention: Since there is no specific treatment of hepatitis-B, it is very important to take preventive measures against the disease. These are as follows:
- [1] Vaccination (Active immunization): HBV infection can be prevented by active immunization using hepatitis-B vaccine. Two types vaccines are available—plasma derived vaccine and yeast derived vaccine (a genetically engineered vaccine).

[2] Passive immunization: Hepatitis-B immunoglobulin (HBIG) is now available which should be given immediately after an accidental inoculation (or exposure to

HBV infected blood).

[3] Other measures: (a) All blood donor should be screened for HBV infection. (b) Surgical and all skin piercing instruments should be sterilized. (c) Sharing of articles like razors, blades, needles to be avoided. (d) Sexual promiscuity to be avoided and HBV carriers should use condom during sexual intercourse. (e) Health personnel should be alerted to avoid blood contact with HBV infected patients.

10.6. Polio Immunization: Pulse Polio

• What is Polio: Poliomyelitis (commonly known as polio) is an acute viral infection caused by a RNA virus (polio virus) which may affect the central nervous system (CNS) to cause paralysis and even death. The polio virus enters the body

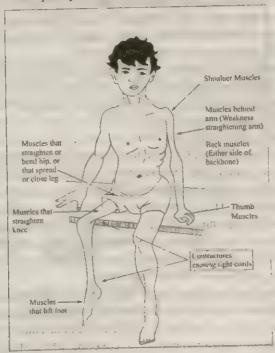


Fig. 10.3: Different Muscles of Human Body weakened by polio infection.

mainly through contaminated food and water or through droplet infection. It multiplies in the gastrointestinal tract. The virus is found in feces and oropharyngeal secretions of an infected person through which it is transmitted to other persons. From the intestine, the virus enters the bloodstream and lymphatic system, and may reach the CNS where it destroys the neurons causing paralysis of muscles and muscle wasting. The limb muscles are often affected. The disease may also cause death if the respiratory muscles are paralysed. The disease occurs mainly in children (hence it is also called **infantile paralysis**) but adults may also be affected. The incubation period of polio virus is 7-14 days, *i.e.*, symptoms of the disease appear 7-14 days after infection. The early symptoms are sore throat, cough, fever, headache, nausea, vomiting, malaise, pain, stiffness in neck and back muscles *etc*. Diagnosis of the disease at early stage is difficult because many of the symptoms resemble those of common cold (flu). Muscle paralysis occurs in a few cases only, when the CNS is affected. Many people may have the infection in mild form often without knowing it but they may transmit the infection.

• Polio immunization: Polio, the crippling disease, is not curable but it can be prevented by active immunization using polio vaccines. Two types of polio vaccines are available (1) Inactivated polio vaccine (IPV) and (2) Oral polio vaccine (OPV).

IPV was discovered by Salk in 1954 (hence also known as Salk polio vaccine). It consists of inactivated (or killed) polio virus and it is administered by subcutaneous or intramuscular injection. Immunization with IPV requires four initial (or primary) doses: 1st dose is usually given when the baby is 6 weeks old, the 2nd and 3rd doses are given at intervals of 1-2 months and the 4th dose is given 6-12 months after the 3rd dose. Additional booster doses are to be given prior to school entry and then every 5 years upto the age of 18 years.

OPV was discovered by Sabin in 1957 (hence also called Sabin polio vaccine). It contains live attenuated (weakend) polio virus. Immunization with OPV requires four initial doses: 1st dose is given at birth (before discharge from the hospital), the 2nd, 3rd and 4th doses are given at the age of 6 weeks, 10 weeks and 14 weeks respectively. One booster dose of OPV is to be given 12-18 months later.

Both the vaccines (IPV and OPV) induce production of antibody in blood against polio virus and can protect the recipient from paralytic polio. But the OPV is now more widely used for routine immunization of children against polio because of its following advantages: [1] It is cheaper. [2] It is easy to administer (because it is given orally and not by injection). [3] It produces antibody more quickly. [4] It induces humoral and local (intestinal) immunity so that reinfection of the intestine is prevented. But IPV does not induce local immunity; so, the intestine can be reinfected to be a source of infection for others.

• Pulse polio: Routine immunization with OPV can prevent polio in the recipient but it is not sufficient to eradicate polio from a country having dense population and poor sanitation as in India. Eradication of polio from our country is possible only by simultaneous mass immunization with OPV covering 100% of the population at risk. For this, the Government of India has launched the pulse polio programme. Pulse

polio is a nation wide mass immunization programme in which OPV is given free of cost to all children upto the age of 5 years in the country on the same day. Pulse polio days are observed at an interval of 4 6 weeks in a year, usually during the low transmission season of polio i.e., between November to February. In each pulse polio day all children upto 5 yrs of age should be given the dose of OPV irrespective of their previous immunization with OPV.

The doses of OPV given during the pulse polio days are 'additional doses' which supplement and do not replace the routine immunization. Pulse polio programmes involve mass campaigns through news papers, radio, television, signboards, hoardings etc. The Government of India has decided to continue the yearly pulse polio programmes until the disease is eradicated from the country. In spite of the massive efforts, the pulse polio programmes have not been 100% successful because many people are not bringing their children to the pulse polio centres. So, health workers are now visiting the houses to give OPV to all children below 5 years of age in the family; this is called mopping up programme.

10.7. Amniocentesis

- Definition: Amniocentesis means withdrawal of a sample of amniotic fluid from a pregnant woman by piercing the amniotic sac through the abdominal wall.
- What is amniotic fluid? Amniotic fluid is the fluid contained within the amniotic sac which surrounds the growing fetus like a cushion to protect it from external pressure. The fluid contains some living cells swept from inside the body of the fetus (because the fluid is constantly being swallowed by the fetus and passes through its gut) as well as shed from the skin of fetus or the amnion. The amniotic fluid also contains urine (i.e., metabolic by-products) of the fetus.
- Process of amniocentesis: A hollow needle is inserted into the amniotic sac through the walls of abdomen and uterus using a local anesthetic. For inserting the

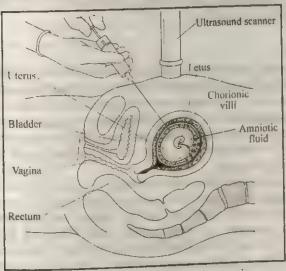


Fig. 10.4: The process of amniocentesis.

needle properly, an ultrasound scanner is used which shows the position of fetus and placenta on a screen and guides the needle into the right place without causing any damage to fetus and placenta. About 20 ml of amniotic fluid is sucked out with the help of a syringe. The amniotic sac is tough and seals itself after removal of the needle.

• Use (or importance) of amniocentesis: Amniocentesis is a prenatal diagnostic technique. The sample of amniotic fluid collected by this is used for two purposes:

- [1] Karvotype analysis of the fetal cells. It means determination of the continuous analysis of the fetal cells. It means determination of the continuous food a control of the product of fetal control of the fetal contr
- [2] Brochemical analysis. Certic Inborn errors of metabolism (e.g., Le. S.), and the Congenital diseases. The conjugate Society of the conjugate Society of the Conjugate Society brochemical and the conjugate Society of the conjugate of analysis fluid collected by ammineentesis.

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- Missise of ammocentesis: It is care to determine the sex of the fetus by extra mine the next constraints. It is tealled, pre-cirl to a morphe of amount for a source of the law is a source of the female fetus in the source of the source of the female fetus in the source of the source of the female fetus in the source of t
- When ammocentesis is recommended * Constrained to use and misuse, it is a property of the parents of the par

10.8. Inequality Of Sexes

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10.9. Female Feticide

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10.10. A Few Comparisons

10.10 1 DIFFERENCE BETWEEN MARASMUS AND KWASHIOKOR

Marasmus	Kwashintkii		
[1] Caused by deficiency of both protein and calorie			
(2) Occurs in infants between 6-18 months of age	[2] Occurs in children older than 1 yr (2 4 yrs of age)		
dehydration may occur	[1] Oedema occurs with moon face		
akin becomes louse.	[4] Subcutaneous fat present and skin does not become louse [5] Skin lesion occurs with hyperpig-		
[5] Skin becomes dry but there is no lesion	mentation,		

10.10.2. DIFFERENCE BETWEEN SYPHILIS AND GONORRHEA

Syphilis	Gonorrhea		
[1] It is caused by a spirochaete	[1] It is caused by a Gram negative		
Treponema pallidum.	coccus Neisseria gonorrhoeae.		
[2] It can be transmitted from mother to	[2] It is not transmitted through		
baby through placenta.	placenta.		
[3] It produces chancres (painless	[3] It produces dysuria (pain on passing		
ulcers) and gummas (tumor like	urine) and discharge of pus from		
masses).	genitalia.		
[4] In untreated cases, it may cause	[4] In untreated cases, it causes sterility		
serious damage of central nervous	but does not affect the central		
system but does not cause sterility.	nervous system.		

10.10.3. DIFFERENCE BETWEEN AIDS AND HEPATITIS-B

AIDS	Hepatitis-B
[1] Its causative agent is a RNA virus called HIV (human immuno deficiency virus).	[1] Its causative agent is a DNA-virus called HBV (hepatitis-B virus).
[2] Incubation period of the virus is few weeks to 6 years or more.	[2] Incubation period of the virus is 6 weeks to 6 months.
[3] All HIV infected persons may not develop symptoms of AIDS. In AIDS immunity of the body is suppressed so that secondary opportunistic infections develop which may be fatal.	[3] Symptoms develop suddenly. It affects mainly the liver which may even cause liver cancer and death.
[4] It cannot be prevented by vaccination.	[4] It can be prevented by vaccination.

10.10.4. DIFFERENCE BETWEEN INACTIVATED POLIO VACCINE (IPV) AND ORAL POLIO VACCINE (OPV)

IPV	OPV		
 [1] It contains killed polio virus. [2] It is given by intramuscular or subcutaneous injection. [3] It is difficult to prepare, hence costly. 	[1] It contains live attenuated polio virus.[2] It is given orally.		
[4] It induces humoral immunity but not local immunity. So, it does not prevent reinfection.	 [3] It is easy to prepare, hence cheaper. [4] It induces both humoral and local immunity. So, it prevents reinfection. [5] It is useful for controlling epidemics. 		

10.11. Matters To Recollect

- Balanced diet means a diet containing all nutrients in adequate quantities and correct proportions, capable of maintaining good health of an individual.
- Carbohydrate and fat rich foods are energy yielding foods.
- Proteins rich foods are body building foods.
- Foods rich in vitamins and minerals are called protective foods.
- Mother's milk is the ideal food for infants upto 3-4 months.
- A pregnant woman requires more nutrients for supporting growth and development of the baby in her womb.
- Aged persons require less calorie because of their sedentary habits.
- PCM or Protein calorie malnutration means nutrational deficiency due to inadequacy of protein and calone along with some other nutrients.
- PCM is mainly of two types marasmus and kwashiorkor.
- Iron deficiency causes anaemia.
- lodine deficiency causes goitre.
- A test tube baby is produced by in vitro fertilization-embryo transfer (IVF-ET) technique.
- Syphilis and gonorrhea are bacterial diseases transmitted through sexual intercourse.
- AIDS and hepatitis-B are viral diseases transmitted through sexual as well as blood contact.
- Pulse polio is a nationwide programme of polio immunization for eradication of polio.
- Collection of a sample of amniotic fluid from a pregnant woman is called amniocentesis.

10.12. Summary

For maintaining good health, an individual must have a balanced diet containing all nutrients in adequate amounts and correct proportions. The composition of balanced diet of an individual varies according to the age, sex, physical activity, physiological or pathological state, food habit, economic status etc. Health disorder due to deficiency, excess or imbalance of nutrients is called malnutrition which includes undernutrition and overnutrition. Common examples of undernutrition are protein calorie malnutrition or PCM (also known as protein energy malnutrition or PEM), iron deficiency, iodine deficiency etc. PCM is of two types marasmus and kwashiorkor. Iron and iodine deficiency leads to anaemia and goitre respectively.

Population problem means the problem of excessive increase in human population. It is basically due to the fact that birth rate is higher than the death rate. Various factors are responsible for this. Overpopulation is a curse because it causes unemployment and poverty, shortage of food, shelter and clothing, low level of education, unhealthy hygienic conditions, environmental pollution and many social crimes. Population problem can be controlled by adopting methods of birth control. Infertility is also a problem among some couples. They may have a child by 'in vitro fertilization-embryo transfer' (IVF-ET) or 'test-tube baby' technique.

A group of contagious diseases that spread mainly by sexual contact are called sexually transmitted diseases (STD). They include bacterial diseases like syphilis and gonorrhea', viral diseases like AIDS and hepatitis-B etc. AIDS virus (known as human immunodeficiency virus or HIV) is a RNA virus while hepatitis-B virus is a DNA virus. Polio is a viral disease caused by a RNA virus which may affect the CNS to cause paralysis and atrophy of muscles especially in limbs. Polio is not curable (i.e., once muscles are atrophied and paralysed by polio they cannot be cured) but it can be prevented by vaccination. Oral polio vaccine (OPV) is most widely used to prevent polio. Pulse polio is a nationwide polio immunization programme held on the same day all over the country to eradicate polio.

Amniocentesis is a process for collection of amniotic fluid which is used as a prenatal diagnostic technique for analysis of fetal sex, chromosomal anomaly if any in the fetus and possibility of inborn errors of metabolism in the child to be born. Amniocentesis is often misused for abortion of female fetus. Human beings show inequality of sexes which depends on the sex chromosomes present in an individual. Males are heterogametic but females are homogametic. Sex of an individual depends on the sperm that has fertilized the ovum from which the individual has developed. Female feticide (or termination of pregnancy when the fetus is female) is a social evil.

10.13. Naming / Discovery / Discoverer

- [1] T. R. Malthus (1778) proposed that human population grows geometrically whereas the means of our substinence increase arithmetically.
- [2] Cicely Williams (1933) discovered 'kwashiorkor' and introduced this name.
- [3] Salk (1954) discovered inactivated polio vaccine (IPV).
- [4] Sabin (1957) discovered oral polio vaccine (OPV).
- [5] Blumberg (1963) discovered hepatitis-B virus.
- [6] Steptoe and Edwards (1978) discovered 'test-tube baby' (or IVF-ET) technique.
- [7] Barre-Sinouss (1983) discovered HIV (AIDS virus).

10.14. Answers To Special Questions

- [1] Give the full names of—(a) PCM, (b) AIDS, (c) HIV, (d) HBV, (e) IPV, (f) OPV, (g) IVF, (h) GIFT, (i) ZIFT, (j) MIST.
- Ans. (a) Protein calorie malnutrition. (b) Acquired immuno deficiency syndrome. (c) Human immuno deficiency virus. (d) Hepatitis-B virus. (e) Inactivated polio vaccine (f) Oral polio vaccine. (g) In vitro fertilization. (h) Gamete intrafallopian transfer. (i) Zygote intrafallopian transfer. (j) Micro-insemination sperm transfer.
 - [2] Give two examples of—(a) energy yielding foods, (b) body building foods, (c) protective foods.
- Ans. (a) Sugar and fats (or oils). (b) Fish and egg. (c) Fruits and green leafy vegetables.

- [3] Why is milk considered as an ideal food but not a balanced diet?
- Ans. Milk is considered as an ideal food because it is an excellent natural food which contains more or less all nutrients and no other single natural food contains so many nutrients in such a balanced proportion. However, since milk is relatively deficient in minerals Fe and Cu and vitamins C and D, it cannot be considered as a balanced diet or complete food.
 - [4] What is humanization of cow's milk?
- Ans. Humanization of cow's milk means changing the composition of cow's milk in such a manner that it becomes more or less similar to human milk and suitable for feeding of infants. For this, the cow's milk is diluted with water, and sugar is added to it because the human milk contains less protein and fat but more sugar than the cow's milk.
 - [5] Why should fruit juice be given to infants from the 3rd month?
- Ans. Fruit juice is given to infants to supplement vitamin-C which is deficient in milk.
 - [6] Why mother's milk (or breast milk) is better than any other milk for infant feeding?
- Ans. Mother's milk is the best food for the infants because of the following reasons—
 - (i) The **composition** and **quality** of breast milk is most suitable to meet the requirement of the infants. The breast milk contains easily digestible proteins and fats in such a balanced proportion that the infant can digest them. On the other hand, cow's milk or preparations of tinned milk may not be suitable for infant digestion.
 - (ii) The temperature of breast milk is most suitable for feeding the infant whereas the temperature of any other milk has to be adjusted before feeding.
 - (iii) Mother's milk is directly fed to the child; hence, it does not require boiling and sterilization of the bottles and utensils as required for feeding of other milks.
 - (iv) Mother's milk contains **immunoglobulins** and other materials that provide defence mechanism of the infant. These are not obtained from other milks.
 - [7] Why starchy food (rice, wheat etc.) is not given to the infants before the age of 6 months?
- Ans. In infants, the normal secretion of amylase, particularly the pancreatic amylase, begins at about the age of 6 months. So, they cannot digest starch properly before this age and hence starchy food is not given to them.
- [8] Why is the cow's milk diluted with water for feeding human infants?
- Ans. See answer to Q-4.
 - [9] Why do aged persons require adequate dietary fibres?
- Ans. In aged persons, the bowel movement is decreased. Dietary fibres help in bowel movement. So aged persons require adequate dietary fibres for regular movement and clearance of bowel.
- [10] Mention the cause of following diseases—(a) kwashiorkor, [J.E.E. 1993] (b) marasmus.
- Ans. (a) Dietary deficiency of protein. (b) Dietary deficiency of protein and calorie.

- [11] Name the diseases caused by deficiency of (a) iron and (b) iodine in the body.
- Ans. (a) Anaemia. (b) Goitre.
- [12] Name two sexually transmitted (a) bacterial diseases, (b) viral diseases.
- Ans. (a) Syphilis and gonorrhea. (b) AIDS and hepatitis-B.
- [13] Name two sexually transmitted diseases which are also transmitted through blood contact.
- Ans. AIDS and hepatitis-B.
- [14] Which vaccine is given in pulse polio programme?
- Ans. Oral polio vaccine (OPV).
- [15] Mention the target population for pulse polio programme.
- Ans. All children below 5 years of age in a country.
- [16] Name three methods for determination of fetal sex.
- Ans. (i) Ultra sonography. (ii) Analysis of sex chromosomes in the fetal cells present in the sample of amniotic fluid drawn by amniocentesis. (iii) Analysis of sex chromosomes in the chorionic villi cells obtained by chorionic villus sampling.
- [17] What is the main cause of female feticide?
- Ans. Dowry system in the society for which a female child is thought to be burden on the family.
- [18] What is the utility of in vitro fertilization?
- Ans. By *in vitro* fertilization (test-tube baby) technique an infertile couple may have a child.
- [19] Where does the fetus grow in test tube baby technique?
- Ans. Within the uterus of the mother or the surrogate mother.
- [20] (a) How many pre-embryos are transferred into uterus in IVF-ET?
- (b) At which stage the pre-embryos are transferred?

 Ans. (a) Usually 3 pre-embryos are transferred in each cycle.
 - (b) Pre-embryos at 4-8 cell stage are transferred into the uterus.
- [21] In a balanced diet, usually what should be the ratio of carbohydrates, proteins and lipids?

 [J.E.E. 1997]
- Ans. Carbohydrate: Protein: Lipid=4:1:1.
- [22] How long a newborn can take breast milk only as food ? [J.E.E. 1999]
- Ans. 4-6 months.

A. Long Answer type/Essay type :

- [1] What do you mean by balanced diet? Formulate non-vegetarian balanced diets for a pregnant woman and an aged person both doing sedentary work. (Ans. 10.1)
- Prepare balanced vegetarian diet charts for (a) a pre-school growing child of 5 years, (b) a male student of 18 years age, (c) a female student of 18 years age. (Ans. 10.1)
- [3] What is malnutrition? What is PCM? Discuss briefly about different types of PCM.

 (Ans. 10.2; 10.2.1)
- [4] Give a brief account of nutritional deficiency of iron and iodine. (Ans. 10.2.2; 10.2.3)
- [5] What is population problem? Discuss its causes. (Ans. 10.3)
- [6] What are the adverse effcts of population explosion? (Ans. 10.3)
 [7] Discuss the methods of population control. (Ans. 10.3)
- [8] Briefly describe the process of in vitro fertilization—embryo transfer'. (Ans. 10.4)

	SOCIAL PHYSIOLOGY	
(01	Write briefly about syphilis and gonorrhea. (Ans. 1	0.5.1 ; 10.5.2)
[9]	What is AIDS? How does it spread? What are its symptoms? Mention	
[10]		
	measures.	
[11]	What is hepatitis-B? How is it transmitted? Mention its symptoms	(Apr. 10.5.4)
	measures.	(Ann. 10.5.4)
[12]	What is notice? Write briefly about notic imminization including buist buil	((ving. 10.0)
[13]	What is amniocentesis? Write its uses and misuse.	(Ans. 10.7)
[14]	Discuss briefly the causes of P.C.M.	(Ans. 10.2)
[15]	Discuss the disadvantages of IVF-ET.	(Ans. 10.4)
[16]	Write what you know about inequality of sexes.	(Ans. 10.8)
[17]	Write a brief essay on female feticide.	(Ans. 10.9)
• 1	B. Short answer type:	
[1]	What is balanced diet [J.E.E. 1997, 2003]? In a balanced diet usually what	it should be the
	ratio of carbohydrates, proteins and lipids? [J.E.E. 1997] (Ans. 10.1	; 10.13 Q-21)
[2]	How can you reduce the cost of a balanced diet ?	(Ans. 10.1)
[3]	11111 10 0011 0 1111110 01111110	1 ; 10.13 Q-4)
[4]	From what age an infant should be given cereals? (Ar	s. Table 10.1)
[5]	What is PEM? What are its types?	(Ans. 10.2)
[6]	What do you mean by undernutrition and overnutrition? Give two exan	iples of each.
		(Ans. 10.2)
[7]	'Malnutrition and infection form a vicious cycle'—explain.	(Ans. 10.2.1)
[8]	What measures would you suggest to prevent PCM?	(Ans. 10.2.1)
191	What type of anaemia is caused by iron deficiency?	(Ans. 10.2.2)
[10]	Mention the ill effects of iron deficiency.	(Ans. 10.2.2)
[11]	What is endemic goitre?	(Ans. 10.2.3)
[12]	Why jodine deficiency causes gottre?	(Ans. 10.2.3)
[13]	Mention the factors responsible for population problem.	(Ans. 10.3)
[14]	Who discovered (a) In vitro fertilization, (b) HIV, (c) Hepatitis-B virus,	(d) Inactivated
11	polio vaccine (e) Oral polio vaccine ?	(Ans. 10.12)
[15]	What is superovulation? Why is it induced in IVF-ET technique?	(Ans. 10.4)
[16]	How ova are collected for IVF?	(Ans. 10.4)
[17]	How ova are collected for IVF? What is syphilis?	(Ans. 10.5.1)
[18]		1000000
ITOI	What is gonormea?	(Ans. 10.5.2)
	Name three sexually transmitted diseases that can be transmitted from a p	(Ans. 10.5.2) pregnant woman
[19]	Name three sexually transmitted diseases that can be transmitted from a part to her baby through placenta. (Ans. 10.5.1;	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4)
[19]	Name three sexually transmitted diseases that can be transmitted from a part to her baby through placenta. (Ans. 10.5.1; (Ans. 10.5.1)	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6)
[19]	Name three sexually transmitted diseases that can be transmitted from a part to her baby through placenta. Name two diseases caused by RNA virus. (Ans. 10.5.1; Name one bacterial disease and one viral disease in which central net	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) rvous system is
[19]	Name three sexually transmitted diseases that can be transmitted from a part to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central new offered (Ans. 10.5.1).	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) rvous system is 10.5.1; 10.6)
[19] [20] [21]	Name three sexually transmitted diseases that can be transmitted from a part to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central new offered (Ans. 10.5.1).	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) evous system is a 10.5.1; 10.6) vaccine?
[19]	Name three sexually transmitted diseases that can be transmitted from a part to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central new affected. What are the advantages of oral polio vaccine over the inactivated polio	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4; s. 10.5.3; 10.6) roous system is 10.5.1; 10.6) vaccine?
[19] [20] [21] [22]	Name three sexually transmitted diseases that can be transmitted from a p to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central net affected. What are the advantages of oral polio vaccine over the inactivated polio What is pulse polio?	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) rvous system is 10.5.1; 10.6) vaccine? (Ans. 10.6)
[19] [20] [21] [22] [23]	Name three sexually transmitted diseases that can be transmitted from a p to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central net affected. What are the advantages of oral polio vaccine over the inactivated polio	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) prous system is a 10.5.1; 10.6) vaccine? (Ans. 10.6) (Ans. 10.6) (Ans. 10.8)
[19] [20] [21] [22] [23] [24]	Name three sexually transmitted diseases that can be transmitted from a p to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central ner affected. What are the advantages of oral polio vaccine over the inactivated polio What is pulse polio? What do you mean by inequality of sexes. What is female feticide?	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) rvous system is a. 10.5.1; 10.6) vaccine? (Ans. 10.6) (Ans. 10.6) (Ans. 10.8) (Ans. 10.9)
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[19] [20] [21] [22] [23] [24] [25] [26] [27] [28]	Name three sexually transmitted diseases that can be transmitted from a problem to her baby through placenta. Name two diseases caused by RNA virus. Name one bacterial disease and one viral disease in which central net affected. What are the advantages of oral polio vaccine over the inactivated polio What is pulse polio? What do you mean by inequality of sexes. What is female feticide? How does amniocentesis help in determination of fetal sex? How can successful fertilization in IVF be confirmed? What do you mean by IUI (intrauterine insemination)? What are GIFT and ZIFT?	(Ans. 10.5.2) pregnant woman 10.5.3; 10.5.4) s. 10.5.3; 10.6) ryous system is a. 10.5.1; 10.6) vaccine? (Ans. 10.6) (Ans. 10.8) (Ans. 10.9) (Ans. 10.7) (Ans. 10.4) (Ans. 10.4) (Ans. 10.4)
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[7] Gonorrhea causes:

• 1	D. Write short notes on :
	[1] Marasmus (Ans. 10.2.1). [2] Kwashiorkor (Ans. 10.2.1). [3] Endemic goitre (Ans.
	10.2.3.). 4 In vitro fertilization (Ans. 10.4). [5] AIDS (Ans. 10.5.3). [6] Pulse polio (Ans.
	10.6). [7] Amniocentesis (Ans. 10.7). [8] Inequality of sexes (Ans. 10.8). [9] Hepatitis-B
	(Ans. 10.5.4). [10] Female feticide (Ans. 10.9).
• 1	E. Fill in the blanks:
[11]	A balanced diet contains all the in adequate amounts and correct proportions.
[2]	Iron deficiency causes
[3]	lodine is deficient in soil and water of areas.
[4]	
[5]	In young ones. The two diseases and are transmitted mainly through sexual contact.
[6]	Treponema pallidum infection produces
[7]	HIV suppresses the system of human body.
[8]	Hepatitis-B is mainly a borne infection.
[9]	Polio may cause, and of muscles.
[10]	Amniocentesis can be used for sex determination of the
	. Choose the correct answer from those given in parentheses to complete the following
	sentences:
[1]	Foods rich in iminerals and are called protective foods. (proteins/sugars/vitamins)
[2]	Marasmus is caused by dietary deficiency of (protein / calorie / both protein
	and calorie)
[3]	lodine deficiency produces (anaemia / goitre / rickets)
[4]	Myxoedema is caused by dietary deficiency of (iron / iodine / folic acid /
	protein)
[5]	The surgical method used for male sterilization is (castration / ligation /
141	In IVF-ET technique, the fetus is reared in . (test-tube / petri-dish / uterus)
[6]	Supplies to characterized by
[7]	Syphilis is characterized by (chances / dysuria / discharge of pus through genitalia)
[8]	Gonorrhea is transmitted mainly through (sexual contact / blood transfusion /
fol	sharing of injection needles)
[9]	is a viral disease which can be prevented by vaccination. (AIDS /Syphilis /
121	Gonorrhea / Hepatitis-B)
[10]	In pulse polio programmes, polio vaccine is given (orally / by s.c. injection/
(10)	by i.m. injection)
	G. Multiple choice type questions:
	Which of the following diseases can be cured by using iodized salt?
	(a) Anaemia, (b) Marasmus, (c) Goitre, (d) Kwashiorkor.
	Marasmus is also known as:
	(a) Infantile paralysis, (b) Slimming disease, (c) Starvation disease of infants, (d) None of
121	these. Hypochromic microcytic appenia is caused by deficiency of
[3]	Trypochronic interocytic anachia is caused by deficiency of .
£41	(a) Folic acid, (b) Vitamin B ₁₂ , (c) Iron, (d) All these.
[4]	Iodine deficiency is associated with:
[6]	(a) Goitre, (b) Cretinism, (c) Myxoedema, (d) All these.
[5]	The full name of AIDS is:
	(a) Auto immune deficiency syndrome, (b) Acquired immune deficiency syndrome, (c) Acquired todine deficiency syndrome, (d) Artificial immune deficiency syndrome.
[6]	Which of the following are at high risk of AIDS?
ini	(a) Drug addicts taking drug by injection, (b) Prostitutes, (c) Homosexuals, (d) All these.
	(a) 2105 accrete taking drug of injection, (b) Hostitutes, (c) Holliosexuais, (d) Mil tilese.

(a) Pain on passing urine, (b) Discharge of pus from genitalia, (c) Sterility, (d) All these.

- 181 AIDS is not transmitted through:
 - (a) Blood contact, (b) Sexual contact, (c) Kissing, (d) Sharing of injection needles.
- [9] The central nervous system may be affected in :
 - (a) Syphilis, (b) Polio, (c) Both of these, (d) None of these.
- [10] Amniocentesis is used for detection of : (a) Fetal sex, (b) Chromosomal anomaly in the fetus, (c) Possibility of inborn errors of metabolism, (d) All these.
- [11] AIDS can be cured by :
 - (a) Vaccination, (b) Antibiotic treatment, (c) Both of these, (d) None of these
- [12] Sex of the fetus depends on : (a) Sperm, (b) Ovum. (c) Both sperm and ovum, (d) None of these.
- H. State whether the following statements are true or false :
 - Mother's milk is an ideal food for early infants.
 - [2] Cereals are body building foods.
 - [3] In aged persons, the nutritional requirements of vitamins and minerals are reduced.
 - Endemic goitre was more common in hilly areas. [4]
 - All HIV positive persons may not develop AIDS for years. 151
 - Syphilis may cause sterility. [6]
 - In vitro fertilization is a very simple and cheap technique to overcome sterility.
 - [7] Syphilis and gonorrhea can be cured by antibiotic therapy. 181
 - AIDS and hepatitis-B are vaccine preventable diseases. 191
 - [10] Amniocentesis means collection of cerebrospinal fluid.

Answer to Q. No. E, F, G and H

- E. [1] Nutrients. [2] Anaemia [3] Hilly. [4] Cretinism. [5] Syphilis, Gonorrhea [6] Syphilis [7] Immune. [8] Blood. [9] Paralysis, wasting. [10] Fetus.
- F. [1] Vitamins. [2] Both protein and calorie. [3] Goitre. [4] Iodine. [5] Vasectomy. [6] Uterus. [7] Chancres. [8] Sexual contact. [9] Hepatitis-B. [10] Orally.
- G. [1] (c), [2] (c), [3] (c), [4] (d), [5] (b), [6] (d), [7] (d), [8] (c), [9] (c), [10] (d), [11] (d), [12] (a).
- H. [1] True. [2] False. [3] False. [4] True. [5] True. [6] False. [7] False. [8] True. [9] False. [10] False.

Origin and Evolution of Life

Topics Discussed: Introduction; Theories in relation to the origin of life, Haldane and Oparin Concept; Meaning of evolution; Gradual Complexities of Organisms; Distribution of Life form in time and space; Mechanism of evolution Darwin's theory of natural selection; Modern concept of Natural Selection; Minnery and Colouration; Speciation and Isolation; Species concept; Human evolution; Biodiversity.

Introduction

Evolution means change. Slow and steady changes that take place in the materials are known as evolution. Changes have been taken place in the universe as in stars, sun etc. and this kind of changes called **cosmic evolution**. Changes also occur in social as well as culture of human life that are respectively known as **social evolution** and **cultural evolution**. Changes also occur in matters and elements which are known as **inorganic evolution**. Like cosmic evolution or inorganic evolution, changes also occur in animals and plants that are known as **organic evolution**. So we mean to say that evolution takes place in many spheres. Here we are dealing with organic evolution. We mean, living plants and animals of to day are nothing but modified descendants of the past existed plants and animals. But the main theme of the organic evolution is the *origin of life* and *its gradual evolution*.

Millions of animals and plants are now existed on this earth surface. Through many centuries, naturalists tried their best to gather the knowledge about those varieties of living organims. Naturally many queries about the origin and diversities of animals and plants have been developed in their mind. How actually the life arises on this earth? Where and when the first life appears? Are all the organisms appear at a time or in different times? How they appear? These types of many other problems strike the mind of the peoples. Even before the time of Aristotle (384–322 B.C), biologists are also deeply thinking about those problems. Due to their serious endeavour some of the problems about the origin of life and their diversities have been solved to some extent, still many more problems are yet to be solved.

11.1. Theories In Relation To The Origin of Life

Many theories have been postulated to explain the origin of life on this earth. Some of the theories on the origin of life are given below.

11.1.1.THEORY OF SPECIAL CREATION:

This theory states that life on earth is a special creation by divine or supernatural power; since then the life is continuing to exist in the unchanging condition. This concept has been the teaching of the religious authorities for many centuries. The theory may have some historical importance but it is not based on facts; because there is no evidence that life was created independently.

11.1.2. THEORY OF SPONTANEOUS GENERATION:

For many centuries, the people believed that various forms of organisms were developed directly from the mud, manure and other non-living substances, *i.e.*, living organisms were developed spontaneously from non-living substances *i.e.*, abiogenesis. As for example, fishes, toads and frogs arose from mud; maggots (larva of fly) were developed from decaying flesh and micro-organisms were formed spontaneously from air or water. Even Needham (1745), Buffon (1749) and many others demonstrated once again and promulgated the spontaneous generation of microbes.

It was **Louis Pasteur** (1822-1895), a great French microbiologist who in 1862 demonstrated that living organisms cannot arise from non-living substances, rather originate from pre-existing organisms, *i.e.* biogenesis. Finally the theory of spontaneous generation was disapproved.

11.1.3. THEORY OF CATASTROPHISM

This theory was strongly advocated by a famous French palaeontologist, **Baron** George Cuvier (1769—1832). According to this theory, there had been several creations of the life on the earth. At the end of each creation there was a great catastrophy that had been wiped out the living organisms and a fresh set of life was created again.

This theory can explain the existence of fossils on earth; but failed to explain, how the close relationships have been developed between the fossils of the recent layer with the existing life. So this theory is completely rejected by many geologists including Charles Lyell (1830), a famous geologist of England.

11.1.4.THE COSMOZOIC THEORY

This theory explain that the primitive life may originated in some other planet and from the planet those primitive life accidentally reached the earth. This theory really does not answer how those living matters came to the earth and could withstand the extreme climatic conditions of interplanetory space? However the space scientists are now trying to search out the existance of life or at least organic matter in some other planets.

11.1.5. THEORY OF CHEMOSYNTHESIS

The origin of life is actually concerned about the conditions and mechanisms that are involved in the creation of most primitive living structures. Since the begining of human civilization, man has speculated on the origin of life. The ancient teachings regarding the origin of life were based on purely religious faiths, *i.e.* life is created by some supernatural power. After that man believes for many centuries about the spontaneous origin of life from non-living substances. The modern concept about the origin of life is based on the evolution of simple chemical substances that led to the formation of organic materials such as protein-like compounds. The possible mechanism of origin of life is explained in the theory of chemosynthesis.

HALDANE AND OPARIN CONCEPT (CHEMOSYNTHESIS) ABOUT ORIGIN OF LIFE.

The life of this earth never arises accidently nor by any mysterious ways. Rather life arises in a natural ways through physical and chemical processes that led to synthesise step by step into the complex chemical substances from simpler substance. As the time

passed on, the origin of life was an inevitable phenomenon in the natural environment. In the 20th, century the mystry of life was explored to some extent by the untiring efforts of many scientists like famous Russian biochemist A.I. Oparin (1894-1980), outstanding English biologist J.B.S. Haldane (1892—1964), American scientists Stanley Miller and Sydney Fox etc. Their thoughts and ideas along with their experimental part are now discussed through the theory of chemosynthesis which is also known as Haldane-Oparin theory. This theory explains the origin of life through certain steps. Short account of this theory is given below.

[A] Synthesis of simple organic molecules in the primitive earth:

There is evidence that the earth was created some what between 4.5 to 4.7 billion (One billion – 1000 million) years ago. From the geological record it has been estimated that the first one-celled fossil is of two billion years old. If the simple one-celled organisms appeared about two billion years ago, it can be easily imagined that the first step in the formation of a life definitely started long before of that period. Generally it is assumed that the unification of the different molecules started near about 3 to 4 billion (3000 to 4000 million) years ago. Geochemical evidence also suggests that the conditions of the primitive earth about 3 to 4 billion years ago were quite different from the present time. The earth at that time was too hot and the atmosphere was a reducing one rather than an oxidising one as now. There was no free oxygen in the atmosphere. At that time earth's atmosphere consisted of methane (CH₄), ammonia (NH₃), hydrogen (H₂) and water vapour (H₂O). This water vapour is thought to have been formed primarily from volcanic activity. In the production of organic substances carbon, oxygen, hydrogen and nitrogen like four elements are essential. Those four fundamental elements were present in the compounds of the primitive atmosphere.

According to the *Haldane-Oparin theory*, the first step towards the origin of life must have been the synthesis of simple organic molecules and those simple organic molecules were formed through series of chemical reactions among the above four simple gases such as hydrogen, methane, ammonia and water vapour. The theory also suggests that the energy that was required for the series of chemical reactions came from the action of lightning, ultra-violet radiation or cosmic ray. As a result, the synthesis of simple organic molecules such as ammo acids, simple sugars, simple fatty acids and simple nucleic acid (purines and pyrimidines) took place in the atmosphere. It is thought that those simple organic molecules were subsequently brought down in the earth's surface by heavy rains. In course of time those organic molecules were accumulated in the primitive ocean. Thus the primitive ocean contained those organic molecules and the ocean became a kind of 'organic soup'.

[B] Stanley Miller's experiment:

In 1953, Stanley Miller tried to prove the idea of Haldane-Oparin theory in his own laboratory at the University of Chicago. He created the primitive atmosphere containing a mixture of hydrogen, methane, animonia and water vapour in one chamber of his own invented glass apparatus. Miller then allowed a discharge of high frequency spark on the mixture of gases for about a week. During this period, water vapour was also supplied from the boiling water in the apparatus. At the end of the week, he collected the liquid from the another part of the apparatus and analysed the chemical composition

of the liquid. He obtained the different types of amino acids (glycine, alanine etc.), simple sugars and other organic substances. Afterwards from the same raw materials Melvin Calvin by using gamma ray recovered mixture of amino acids, purines and pyrimidines which are the building blocks of nucleic acid. Subsequently many other scientists experiments and recovered organic molecules from inorganic substances. Thus the experiments of Miller, Calvin and of other scientists provide support to the Haldane-Oparin theory and they show that such events could have taken place in the primitive earth.

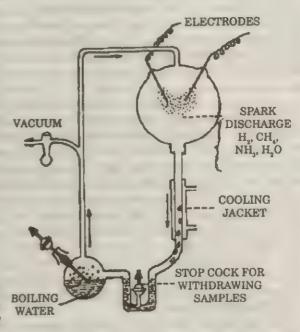


Fig. 11.1: The apparatus set up by Miller to synthesize organic compounds under primitive earth conditions

[C] Synthesis of macro-molecules:

Simple organic molecules are now synthesize among themselves. As a result, different types of macro-molecules are formed, such as large number of anino acids are united to form peptides and large number of glucose molecules are united to form starch.

Naturally question may arise, how and in what condition those macro-molecules are formed in the primitive earth? Are the proteins, carbohydrates and fats of the primitive earth similar to the present day materials? Sydney Fox of Florida State University made many experiments only to explore those problems. He thought that the heat energy of the primitive earth is responsible for the synthesis of polypeptides from simple organic molecules. Accordingly he experimented and observed that the polypeptides have been synthesised from amino acids by heating to boiling and then cooling; nucleic acids have been formed from purines and pyrimidines by heating under pressure. So the laboratory experiments show that such events may happened in the primitive earth. Sydney Fox also proved that the proteins which have developed by heating are also similar to the proteins of the present day living organism, because both the types of proteins are being splitted by pepsin and other protein splitted enzynmes. After Fox, many other scientists made similar experiments and they were able to produce complex organic materials. So we can say that the early proteins and nucleic acids have been developed without any enzymatic process. Development of macro-molecules in the primitive earth paved another step in the origin of life.

[D] Coacervate model of Oparin:

Macro-molecules of the primitive ocean were united again one with the other mainly by their force of attraction and form supramolecular structures. In this way, the complexity of molecules were developed in the primitive ocean. In order to explain this, Oparin in 1938 suggested his coacervate model. According to the proposal, the solution of supramolecular structures is known as a coacervate. In the primitive ocean, the supramolecular structure is covered with a fine membrance which is formed due to the surface tention. Sydney Fox subsequently made experiments on the idea of Oparin, He observed that the proteins which are developed by heating system are also aggregated to form small droplet-like structures and these droplets are known as proteinoids. These proteinoids with water having an outer limiting membrane are called microspheres or spherules what Oparin regards them as coacervates. Fox also observed that the spherules contract after adding sodium chloride solution on the surrounding medium. Fox explained this phenomenon in the light of osmosis; as the water comes out, the spherules are contracted. According to the opinion of Oparin and Fox, after the formation of supramolecular structures of protein there is a formation of outer limiting membrane. As a result, some characteristic features of life have been expressed in these organised coacervates. Thus it may be said that the protein coacervates are believed to have given rise to the first living organism or it may be considered as a structure prior to the origin of living organism in this earth.

[E] Origin of primitive cells:

The next step in the origin of life is the introduction of nucleic acids inside the protein coacervates and thus became organised to form cells. How the nucleic acids were introduced inside the coacervates? Though this problem cannot be explained properly; yet this nucleic acids are controlling the functions and reproductin of the cells. This primitive cells absorb molecules from their environment for nutrition and they respire by anaerobic process as there is no free oxygen in the primitive earth. They can divide asexually and thus remind us of bacteria and other unicellular organisms of the present day.

Subsequently some of these primitive cells utilized the rays and synthesize their own food. Thus photosynthetic organisms are belived to have evolved near about 3500 million years ago. These primitive organisms release oxygen to the atmosphere as a byproduct of photosynthesis and makes the atmosphere as an oxidising one. The free oxygen in the atmosphere now prevents the abiotic origin of life. So we can conclude, that the life will not be evolved now from the inorganic substances rather life will arise from the pre-existing living organisms.

11.2. Meaning of evolution

The word evolution (L=evolvere) means to unfold or to reveal hidden potentialities. Evolution in its broad sense simply means an orderly change from one state to another, such as cosmic evolution or inorganic evolution.

But the slow and steady changes in the properties of organisms over the course of generations are regarded as organic evolution. In short we can say that it is descent with modifications. In general, slow and steady changes of the organism that have given rise to diversities of life from simpler to more higher complex form.

11.3. Gradual Complexities of Life

After the origin of protoplasmic material by the abiotic process in the primitive world, the unicellular organisms were developed. According to the opinion of some

biologists, some of those primitive cells were heterotrophic and some were photosynthetic cells (autotrophs). Probably the heterotrophic cells were modified subsequently and gave rise to unicellular animals and autotrophic cells were developed into unicellular plants. So those two branches (animals and plants) gradually proceeded into two separate streams and slowly more and more complex animals and plants appeared on this earth surface. A short account of the gradual complexities of animals and plants are given below.

[A] Gradual complexities in animal kingdom:

We are observing the varieties of animals on this earth surface. The animals from Amoeba to man appear slowly and steadily from the pre-existing ancestors. We can say that the origin of Amoeba-like unicellular protozoa is the first step in the formation of animal kingdom. After the simple type of unicellular protozoans, many varieties of multicellular invertebrates appear on the living world and they appear step by step through billion's years of earth's history. From the unicellular protozoa, multicellular sponge like porifera group arises and this is the first multicellular group without any tissue grade of organization. Subsequently two layered Hydra like cnidarian animals are developed. After cnidaria, three layered but accelomate helminthes originates. Next we find a more complex cockroach and prawn-like arthropods are evolved. After the arthropoda, snail and Octopus-like molluscan animals appear on this living world. Starfish-like echinoderms develop as a last step in the invertebrate series. After the invertebrates, the chordates appear on this living world. Among the vertebrates, cyclostomes are the first group of animals that evolve on this earth. Cyclostomes are jawless primitive vertebrate. Then appear the higher vertebrates with their jaws. Among the higher vertebrates, first appear the fishes then the amphibians. Some of the amphibians are somehow adapted on the land. After the amphibians, reptiles were evolved and adapted on land. From the reptiles, first bird then the mammals were evolved. Man appears at the last part of the mammalian evolution.

[B] Gradual complexities in plant kingdom:

The first group of plants that arises on this earth surface is the non-green unicellular bacteria-like organisms. Subsequently green algae and non-green fungi are developed. These are the simplest plants and their body is made up of single or many cells but without any differentiation into roots, stems or leaves. Algae and fungi are included under the group of thallophyta. Gradually more and more complex multicellular plants are developed from the thallophytes. Fairly simple but more complex than thallophyta, mosses are evolved. Mosses are placed under the group of bryophyta. The bryophytes are green and they have root-like rhizoids and in some leaf-like structure is present. Then ferns evolve which are included in the pterydophyta. They do not bear any flowers but their body is differentiated into roots, stems and leaves. After the ferns, the flowering plants have been developed and they diversed into two groups such as gymnosperm and angiosperm. In gymnosperm seeds are not present within the fruit, i.e. fruits are absent as in Pinus etc. In angiosperm where the plants are highly evolved, seeds are present within the fruit, i.e. fruits have been developed. Lastly, the angiosperms are diversed into two groups such as monocotyledonous (seed with one cotyledon) and dicotyledonous (seed with two cotyledons). Monocotyledons are rice, wheat, maize etc. and dicotyledons are gram, pea etc.

In this way, different types of animals and plants have been evolved on this earth surface through the evolutionary process. All the modern biologists are supporting this evolutionary concept.

11.4. The History of Life as Revealed by the Fossil Record

(DISTRIBUTION OF LIFE FORM IN TIME)

ERA	AGE IN MILLION YEAR	PERIOD	ЕРОСН	TYPES OF LIFE	DOMINANT LIFE	
		QUATER- NARY	RECENT	Rise of human civilization; dominant man.	Age of Man	
CENOZOIC (Modern life)			Pleistoceno	Extinction of great mammals; rise of social life of man.		
			Pliocene	Rise of manJava-man; apes		
		TERTIARY	Miocene	Dominant mammals.	AGE OF MAMMALS	
			Oligocene	Rise of higher mammals; Flowering plants.		
			Eocene	Rise of placental mammals; Extinction of primitive mammals; angiospermic forests.		
	65		Paleocene	Dominant of primitive mammals.		
		CRETACE- OUS		Extinction of dinosaurs; rise of monocot plants.	AGE OF REPTILES	
MESOZOIC (Medieval life)		JURASSIC		Dinosaurs dominant; Archaeopteryx; first mammals and first angiosperms.		
	240	TRIASSIC		Rise of dinosaurs; turtles, crocodiles and dominant cycas and conifers.		
		PERMIAN		Extinction of trilobites, primitive reptiles; cycads and conifers.		
		CARBONI- FEROUS		Radiation of sharks, amphibians abundant, first reptiles and lycopods, abundant gymnosperms.	AGE OF AMPHIB- IANS	
PALAEO- ZOIC (Ancient life)	,	DEVONIAN		Cartilagmous and bony fishes; first amphibians; first crabs and snails; first gymmosperms.		
		SILURIAN		Rise of lung fishes; Scorpions and land plants.	AGE OF FISHES	
		ORDOVICIAN		First vertebrates-Rise of fishes; higher mollusks, corals; rise of land-plants.		
	600	CAMBRIAN		Invertebrates—Trilobites dominant, crustaceans, mollusks, echinoderms, sponges, annelids and marine algae.	AGE OF INVERTE- BRATES	
PROTERO- ZOIC	3800			FOSSILS RARE		
ARCHEO- ZOIC	4600			NO FOSSILS	Probably Unicellular organism and origin of life.	

11.5. Distribution of Life Form in Space

(According to Huxley and Wallace)

REALMS	IMPORTANT REGIONS	IMPORTANT LIFE FORM	
NEARCTIC	North America, Greenland and Canada	Opossum, Racoon, Rattle snake, Axolotl and Necturus.	
NEOTROPICAL Central America, South America, and west Indian Islands.		Tailed monkeys, Marmoset, Llama, Rhea, Tortoise and Vampire bat.	
PALEARCTIC Europe, Asia (including major portion of China, Afghanisthan, Persia and northern to Himalayan mountain) and Africa (northern to Sahara)		Sheep and goat, pheasant, Robin, Magpie.	
ETHIOPIAN	Africa (South of Sahara), Soudi Arabia and Madagascar.	Gorilla, Chimpanzee, Baboon, Zebra. Giraffe, Lion and Hippopotamus.	
ORIENTAL South coast of Asia, India, Ceylon, Bangladesh, Pakistan, Burma, Indonesia, Portion of China and Philippines.		Tree frog, Viper, Python, Crocodile, Gecko, Wood pecker, Cuckoo, Kingfisher, Dove, Peacock, Monkey, Dog, Bear, Elephant, Rhinoceros, Orang-utan and Tiger.	
AUSTRALIAN	Australia, New Guinea, Tasmania and New Zealand.	Dingo, Parrot, Sphenodon, Kiwi, Cassowaries, Paradise bird, Wombat Duck-billed platypus and Marsupial	

11.6. Mechanism of Evolution

There are many evidences that are supporting the organic evolution. These evidences are: (i) Evidences on the basis of morphology, (ii) Evidences from embryology, (iii) Evidences from distribution of form in time (iv) Evidences from distribution of fossils etc.

So, evidences in favour of Organic evolution have come from so many of wide areas that biologists have to agree about the concept of evolution. Due to this evolutionary process, diverse forms of animals and plants have appeared on this earth surface through millions of years. But how or what is the mechanism of evolution by which diverse froms of life were evolved? In this respect, several theories have been formulated in explaining the mechanism of evolution. The theory as proposed by Jean Baptiste de Monet Lamarck popularly known as Lamarck as the theory of 'inheritance of acquired characters'. This theory was published in his book 'Philosophic Zoologique' in 1809. Lamarck was the first man who tried to explain the evolutionary process on scientific point of view. Hugo de Vries proposed 'The Mutation theory' in 1901. This theory of de vries explained that mutation is the only causative factor in species formation and the natural selection has nothing to do in speciation. In 1859 Charles Robert Darwin published his monumental work in the name of 'The Origin of Species by means of natural selection'. Here he explained in detail about the concept of organic evolution by natural selection. So his theory is also known as 'Theory of Natural Selection'.

Before we explain the 'Modern concept of Natural Selection' we like to discuss first the concept of Natural Selection as proposed by Darwin.

11.6.1. DARWIN'S THEORY OF NATURAL SELECTION:

The theory of Darwin which is based on facts and evidences is known as Darwinism. The main concept of Darwinism is the natural selection that operates in the transmission of species. The theory is based on certain principles and these principles are briefly described below.

[1] Prodigality of production:

Reproduction is one of the fundamental characteristics of all living organisms. Darwin observed that each species reproduces at a terrific rate in a geometric ratio. A salmon fish produces 28,000,000 eggs in one season. If such immense number of eggs survive and mature; reproduce again with the same number of eggs, within few years the whole water space of the earth will be filled up only with the fish. Elephant is the slowest breeder amongst the animals. From a pair of elephant approximately three young ones are produced. Darwin observed it and calculated that a single pair of elephant will be able to produce nineteen millions of descendants in 750 years. These vast number of elephants if all were alived, there would have been no space on land for other animals. This geometric multiplication causes overcrowdedness and the struggle for existence becomes inevitable.

[2] Struggle for existence:

Though the reproduction rate is high, yet the food and space for living area never increase proportionately. As a result, there will be keen competition for food and shelter. So this keen competition for survival amongst the living organisms is known as *Struggle for existence*. Struggles are of three kinds and these are—

- [i] Intraspecific struggle: This is a struggle for food and space amongst the individuals of the same species. As for example, many seedlings are produced from a tree that are distributed surrounding the tree. All these seedlings are trying to get light, air and raw materials for food from the surrounding soil. So there will be keen competition amongst the seedlings for procuring the above materials.
- [ii] Interspecific struggle: This is a struggle for food and space between the members of the different species. Innumarable instances are there in the living world. As for instance, tiger is hunting for deer which is their food. But the deer is also trying to escape from the tiger. This type of struggle between the tiger and deer is going on.
- [iii] Environmental struggle: Living organisms are always struggling to alive against the natural calamities such as flood, drought, earthquake etc.

In the living world, plants and animals are always facing those three kinds of struggles. As a result of struggles, death occurs in many organisms. Thus more or less constant number of individuals of a species is maintained.

[3] Variations: Darwin observed that there is a difference in the from and structure among the individuals of a species though there is fundamental similarities. These differences among the individuals of a species are known as variations. These variations are the natural phenomena and act as a raw material of evolution. Variations are of two kinds, favourable and unfavourable. Variations that are helping the organisms to adjust with the environment are regarded as favourable variations. Favourable variations are helping in the struggle for survival and unfavourablee variations are not helping in the struggle, ultimately the organisms fail to survive.

- [4] Survival of the fittest: In nature, continuous competition among the individuals are going on for their survival. Only those individuals which have some favourable heritable variations of structural and functional will be adapt in new conditions. So organisms with such favourable variations have better chance to survive. Consequently those favourable variations will be transmitted to their offsprings. In course of time, these plants and animals will acquire superiority over the rest of the organisms. Those individuals which have unfavourable variations will fail to adapt in the new environment and ultimately they are eliminated from nature. This phenomenon is known as the 'survival of the fittest'.
- [5] Natural selection and speciation: Nature will decide which one is fit and which one is unifit in nature. Nature will select the good varieties and others will be eliminated. This is called natural selection. So natural selection is a sort of weeding out process. Natural selection operates amongst the fittest organism. Favourable variations are preserved in the organisms by natural selection and transmitted to the offsprings. Repeated selection leads to slow and steady modifications of the structure and function in the subsequent generations. In course of time new forms are developed which are quite different from the primitive one. These new forms are stabilised and leads to a new species. In this way, the natural selection operates and new species have been evolved in nature.

The principles of Darwin are summarised below:

	Inductions		Deductions
[i]	Prodigality of production	}	Struggle for existence
[ii]	Constancy of food and space	,	
[i]	Struggle for existence	1	Survival of the fittest
[ii]	Variations and inheritance	5	out vivai of the littest
[i]	Survival of the fittest	1	Origin of species
[ii]	Operation of natural selection	3	Origin or species

Criticism of Darwin's theory: The theory of Darwin on evolution is undoubtedly a revolutionary one but it is not absolutely correct. Though his theory is based on facts with various examples yet he failed to explain in many cases or the explanation that he put forwarded was not based on scientific facts. Some of these are given below.

- [1] Darwin mentioned in his theory that variations occur in the organisms. But he failed to explain the origin of variations. Natural selection can only select the variations which are already available in the living organisms. This is the weak part of Darwinism.
- [2] Another weak part of his theory is the introduction of blending inheritance and subsequently he was the believer of Lamarckian inheritance.
- [3] Natural selection fails to explain the cause of the existence of vestigial structures in the living organisms.
- [4] The existence of huge-sized antlers of the deer cannot be explained on the basis of natural selection.

11.6.2. MODERN CONCEPT OF NATURAL SELECTION

Hugo de Vries, a Dutch botanist introduced the Mutation theory of evolution in 1901. He proposed that new species evolve from earlier species not by natural selection

and accumulation of small continuous variations through generations, but by sudden mutations of individuals. This theory of *de vries* to some extent paved the way towards proper understanding of Darwinian concept of evolution. Besides the change and diversification of organisms through geological time, there are changes in the hereditary materials, *i.e.* evolution at the genetic level. Evolution on the grand scale of geological time is known as **macroevolution** and evolution at the genetic level is known as **microevolution**. In the first part of twentieth century there is incorporation of population genetics into the studies of evolution which led to the emergence of comprehensive theory of evolution which is known as **modern synthesis**. The modern synthesis emphasises the importance of populations as the units of evolution, wherein natural selection play a central role in the formation of new species.

• Population geneties and evolution :

A population may be defined as all individuals of the same species occurring in the same area at a particular time and the population geneties is the study of the frequencies of genes in populations. It represents an application of Mendelian geneties to Darwinian natural selection.

Evolution takes place within populations, when the relative frequencies of different variations of gene change over time, such as, if there are two forms of a specific enzyme in a population certainly there is evolution, provided the relative frequencies of the individuals possessing each form of enzyme change.

In 1908, G.H. Hardy and W. Weinberg independently defined the genetic structure of a non-evolving population. They observed that hereditary conservation of genes is the characteristic of a population. This principle is known as Hardy-Weinberg equilibrium. This principle states that under certain conditions of stability allelic frequencies remain constant in the subsequent generations of sexually reproducing organisms. We can otherwise say that all the factors if remain constant, the frequency of particular genes and alleles will remain constant in a population through subsequent generations. This kind of stability at the genetic level is known as genetic equilibrium. The Hardy-Weinberg Principle helps the geneticists to determine the time and degree of evolutionary change. Geneticists used this principle to calculate allelic frequency at a starting point and then compare it to frequencies measured at some future time. The amount of deviation between observed frequencies and those predicted by Hardy-Weinberg Principle indicates the degree of evolutionary change. Hence evolution occurs when there is upset of equilibrium. In other way, evolution is a departure from Hardy-Weinberg equilibrium.

Sources of Variation :

The individuals of a population share a number of important features but differ from one another in several ways. Generally no two members of a population are exactly alike. The differences of characteristics between members of the same species are called variation. Variation is the raw material of evolution. Evolutionary agents are acting on this variation. Therefore, a population to evolve its members must possess variation. Variation is observed both at the *phenotypic level* and at the *genotypic level*. Natural selection acts on the genotypic level. Hence genetic variation is the pre-requisite of evolution. In other words, evolution requires genetic variation. Genetic variation occurs by certain mechanisms and these mechanisms cause diviations from Hardy-

Weinberg equilibrium There are five basic mechanisms which cause variation at the genetic level. These processes are given here, such as *mutation*, recombination, gene migration, genetic drift and natural selection.

- (a) Mutation: A mutation is a sudden heritable change in the characteristic of the organism. These mutations occur in random fashion irrespective to the adaptive needs of the organisms. Mutations are mostly harmful or neutral to the organisms. However, if the environment changes, the alleles which were previously narmful or neutral may become advantageous. So far studied, mutation rate is slow. Normally one mutation occurs in one million. Still these mutation rates are quite sufficient to create considerable genetic variation. The changed environment does not induce mutation rather it only selects the preadaptive mutations which are already existed in the population. Mutations restore those alleles in the population which are removed by the other evolutionary agents. Thus, mutations not only create variations but also help in maintaining variations within population. Mutations also introduce new genes and alleles into the gene pool (it is the sum total of all the genotypes or alleles present in a population). It is the gene pool, in which new genes or variants of alleles are added or removed. This variability of genes or alleles in a gene pool, is the raw material for evolutionary change.
- (b) **Recombination:** There is a reshuffling of gene combinations. Thus provides new combinations of existing genes and alleles. There are different ways of recombination of genes and alleles, such as independent assortment of chromosomes during meiosis, crossing over during meiosis and during tertilization, random fusion of gametes and also within genes. Thus recombination adds new alleles and allele combinations to the gene pool. Hence recombination acts as an agent of evolution.
- (c) Gene migration (Gene flow): Some times few populations are completely isolated from the other populations of the same species and also some migration occurs between the populations of a species. If the migrating organisms breed within the new populations then the immigrants will transfer new alleles to the local gene pool of the host population. This transfer of alleles to the local gene pool of the host population is called gene migratin or gene flow. If the migrated species is closely related with the host species then fertile hybrids may develop from interspecific mating. Then these hybrids will carry genes from species to species. Therefore, diffusion of genes into a population occurs as a result of migration. When the gene flow is continued then it decreases the differences between the gene pools. As a result, the differences between the separated populations are being reduced.
- (d) Genetic drift: The random changes or errors in the allele frequency which is caused by chance alone are called genetic drift. It is a binomial sampling error of the gene pool. Sampling errors or changes often lead to the elimination of certain alleles and fixation of some genes. In this way, it reduces the genetic variability of the population. In other words, we can say that the elimination of certain genes in a small isolated population either due to intensive inbreeding that is caused permanent fixation of some genes or death of a small section of population by natural calamity. The effect of genetic drift is large in a small population. In a small population a natural calamity may increase the frequency of a character which has small adaptive value. Thus genetic drift can bring about significant changes in the allele frequencies in a population to a new habitat. Sometime their phenotypic characters are suddenly changes and they are quite different from the parental population; as a result, they are forming a new species.

(e) Natural Selection: It is the most important evolutionary process which brings to changes in allele frequencies and favours adaptation as a product of evolution. Natural selection also checks the disharmonising effects of the other processes that are not leading to adaptation. The individuals of having pre-existing classes of genetic variants in the gene pool are well adapted then they survive longer period and reproduce more offsprings. This is known as differential reproduction. Through such differential reproduction, adaptive alleles are selected and transferred to the next generation. Thus increase in frequency over subsequent generations. In case of less adapted alleles which are present in reproductively less successful individuals are failed to select. According to Darwinian terms, survival and fertility mechanisms which promote differential reproduction are known as selection. In modern terms, selection is the consistent differences in the contribution of various genotypes to the next generation. Both the views taken into consideration, we can say that the natural selection is the process of differential reproduction which leads to differential contribution of genotypes to the gene pool of the next generation.

Natural selection causes a change in allelic frequencies of a population. The effect of natural selection on various traits are of three kinds, such as stabilising selection

directional selection and disruptive selection.

(i) Stabilising selection: If the largest and the smallest individuals in a population are producing relatively fewer offsprings to the next generation than those closer to the average size, stabilising selection is in operation. In such a selection, variation is reduced but the mean value is not being changed. Here rates of evolution are very slow as the natural selection is stabilising.

(ii) Directional selection: If the individuals of one extreme of the size (larger ones) produce more offsprings to the next generation than the individuals of other extreme size, then the mean size of individuals in the population will increase. In such case, directional selection is operating. Directional selection if operates for many generations, there will be trend of evolution within the population.

(iii) Disruptive selection: If natural selection simultaneously favours the individuals at both extremes of size then disruptive selection is operating. This kind of selection is rare.

11.7. Mimicry and Colouration

11.7.1. MIMICRY:

- Definition of mimicry: Mimicry may be fined as a special kind of protective adaptation serving to ensure better survival of the species.
- Explanation of mimicry: It has been observed that animals are being attacked by enemies. So they have developed several devices to protect themselves. In nature, there are some harmless animals which are unable to protect themselves. But they develop the same warning colours and shapes just like another animal which is well protected due to the presence of poison, bad small, acrid taste etc. This type of well protected animal is unacceptable to the enemy or predator. Thus the harmless animal which imitates the another well protected animal is known the 'mimic' and the well protected imitated animal is known as the 'model' Therefore mimicry is used to denote the deceptive resemblance of the mimic to a model. Model is another species of animal

which is well protected. Hence the 'mimic' is avoided by the predator due to its deceptive appearance just like 'model'

Bates, an English naturalist who for the first time explained the mimicry on scientific point of view. He observed the butterflies of two separate families; One family of butterflies was edible to insectivorous birds but the butterflies of another family were inedible to insectivorous birds due to its unpleasant taste. The harmless butterflies imitate not only in wing texture but also in colour, spotting and other characters in minute details of inedible butterflies. So when the members of both the families flew together, their external appearance so indistinguishable that the insectivorous birds were confused. Thus the harmless edible butterflies were saved from the predator. Here the harmless butterflies mimic the harmful butterflies and the phenomenon was called mimicry.

Examples of mimicry :

- (i) There is a powerful sting in **Bees.** They use this sting against the enemy. In this way they protect themselves against the predator. Certain flies of Dipteran otder imitate very closely with the bees.
- (ii) Ants are inedable by some birds. Some species of spiders manual ants. Certain bugs also mimic ants.
- (iii) Wasps are well protected by their sting. Certain flies mimic the wasps and certain moths mimic the wasp.

• Mimicry is effective under the following conditions:

- (a) Mimicry is more effective in the forest area.
- (b) Mimicry involves structure and behaviour.
- (c) Mimicry is more effective where mimic and model fly together in the same geographical area.

• Causative factor of mimicry:

It has been stated that the resemblance between the mimic and the model is due to the effect of similar environmental factors. But Fisher stated that there is a tendency for disadvantageous genes to become recessive and for advantageous genes to become dominant. Some stated that mimicry was developed due to a single *gene mutation*. Resemblance between the mimic and the model is perfected by the action of modfying genes and *natural selection*. It has been shown that mimicry is improved during the course of time by the selection of suitable modifiers. Hence the mimicry is developed due to the action of genes and natural selection.

11.7.2. COLOURATION:

Colouration of living organisms is also one form of adaptation. This type of adaptation helps the living organisms to protect them from the attack of a natural enemy. Colouration of the animal agrees with that of the surroundings so that a natural enemy is unable to distinguish the prey from the background. This type of protective colouration is observed in many animals.

Animals have taken many devices to conceal them from the enemy. In some cases the resemblance not only in colour but also in shape and other structural details with some other object of the background.

Following examples illustrate the protective colouration-

- (i) Leaf insect (Phyllium bioculatum) shows not only bright green colour but also the wings show resemblance a leaf in shape with venation and even the legs of the insect exibit leaf-like, so that the insect perfectly resembles with a green leaf. Thus the leaf insect protects from the attack of a natural enemy.
- (ii) The wings of dead leaf butterfly (Kallima) are brightly coloured on the upper surface but the lower surface is dull brown like a dry leaf. When the butterfly sits on a twig with its wings folded on the dorsal side of the body, the dull brown coloured lower surface of wing is exposed. In this position, the wings resemble a leaf in shape and the butterfly is indistinguishable from a dry leaf. Thus the butterfly is protected from the predator.
- (iii) The colour and shape of Coterpillars of a moth resemble with small turigs During the rest, the caterpillars become stiffen and stand out from the branch of a plant at an exact angle of a twig. Thus it is extremely difficult to distinguish them from the surrounding twig. In this way, it escapes from the natural enemy.
- (iv) Many insects are cryptic colouration in appearance during their rest period. At the time of flight there is a flash of colour which frightens the enemy for a moment. Thus the insect escapes from the attack of a predator.
- (v) Peppered moth (Biston betularia) lives in all parts of England. This moth shows cryptic colouration with two varieties, such as light (grey colour) and dark (black colour). The black (melanic) peppered moth became more and more abundant than the light (grey) peppered, mainly in and around industrial cities like Manchester and Barmingham. This type of change of colour in the population of peppered moth is an example of evolution. Biologists proposed that before industrial pollution, the typical light (grey) form of peppered moth succeeded to camouflage well against the pale tree trunks on which the moths used to rest dwing day time. Subsequent to industrial smoke and soot, the pale or grey tree trunks became more and more blackened. As a result, the light coloured moth is easily detected by the predators than the black variety of moth. This resulted a decrease in the number of light moths and increase in the number of black variety. Hence evolution favoured the black moths to adapt in the polluted areas of England. Evolution of black moth in response to industrial pollution is known as industrial melanism.

Colouration and Natural Selection :

Darwin stated that evolution has taken place by natural selection. Also we have learnt that an evolutionary change has a genetic basis which causes hereditary variation. This hereditary variation or genetic variation if favoured by natural selection, helps the organism to adapt to a particular environment. Hence any evolutionary adaptation must have its basis at the genetic level.

Thus it is obvious that the protective devices which are taken by animals have been evolved by the action of natural selection. A mutation in any population that changes the colour pattern in such a way as to give protection from the predator, will be preserved by natural selection.

Barnard Kettlewell in 1958, a British elologist made an experiment on industrial melanism by an ingenious method. He demonstrated that the dark coloured (melanic) moths are protected on dark trees in industrial areas and light coloured peppered moths

are easily identified and caught by predator in large numbers. Thus he deduced that industrial areas offer great protection to melanic forms.

11.8. Speciation and Isolation

The process by which one or more new species are formed from an existing species is called speciation. The division of a single population into two or more separate groups due to some kind of barrier so that there will be no interbreeding is called isolation.

11.8.1 ISOLATING MECHANISMS:

According to Dobzhansky, the isolating mechanisms that can lead to the emergence of new species are classified into the following types:

1. Geographical Isolation

Sometimes a population is separated into two or more groups by some geographical barrier and thus prevented from interbreeding. These barriers are high mountains, deserts, dense forests, Ocean and extremes of temperature and they serve as effective barriers. These barriers prevent the exchange of genes between the isolated populations. Darwin's finches which are separated from the original range are formed separate species in Galapagos islands.

2. Environmental Isolation (Ecological isolation)

Populations that are living under different environmental conditions remain isolated from one another and are prevented from interbreeding. Environmental isolation depends upon food habits and other physislogical requirements of the organisms. As for example, an insect which lives only in conferous trees is environmentally isolated from another insect which lives only the deciduous trees; although both are living in the same forest. Environmental isolotion is more effective in plants.

Geographical and environmental isolations prevent the individuals from coming into contact with each other.

3. Reproductive Isolation

Even though two populations may not be environmentally or ecologically separated yet they may be effectively isolated as they failed to interbreed. This is reffered to as reproductive isolation. There are several types of reproductive isolation which are given below.

- (1) Mechanical isolation—The genital structure in two populations is so different from each other that copulation between males of one population and females of the other is impossible. Structural difference in the genitalia causes specific isolation. Such a condition is seen in insects.
- (ii) Seasonal isolation—Breeding season of two groups of animals or two groups of plants do not coincide. As for example, flowers of one population of plants become mature before the flowers of another population. Thus pollination of flowering plant is impossible between the two populations.
- (iii) Psychological isolation—In animals, courtship behaviour of one fails to stimulate the other. In many insects and birds, there is an elaborate courtship before copulation. But this process of courtship is different in details among the closely related species. Thus there is a tendency of selecting mating. Hence this type of isolation is reffered to as sexual isolation which is based on psychological differences.

- (iv) **Physiological isolation**—In many cases, matings may occur between the different species but zygote may not form as a result of mating. This type of barrier serves to prevent the fertilization of the gamete. For example, sperms of male *Drosophila* fail to survive in the receptacle of the female of other species; pollen tube of a plant does not develop upto the style of a female flower.
- (v) Hybrid inviability—Interspecific fertilization may takes place but the hybrid organism is inviable. Hybrids die before reaching sexual maturity.
- (vi) Hybrid sterility—Normal vigorous hybrids do not produce functional gametes *i.e.* they are sterile. Classical example of hybrid sterility is **mule** which is produced from the mating of a male donkey and a female horse. Similarly, mating between male horse and female donkey produces a hybrid which is known as **hinny**. The hinny is also sterile.
- (vii) **Hybrid breakdown**—If the hybrids are fertile, the offsprings of hybrid are weak and infertile. Thus further reproduction does not occur. Hence offsprings are not produced by them.

11.8. 2 ISOLATION AND SPECIES FORMATION:

In the formation of new species some kind of isolation is necessary Frequently such isolation is geographic or environmental. Hence geographic or environmental isolation is necessory as a first step to produce genetic differences between geographically isolated populations. Such isolation provides the opportunity for each population to evolve along its own lines. Geographically isolated (i.e. allopatric) populations become differentiated and give rise to reproductive isolation. Thus when a population becomes adapted to different environments, a reshuffling and recombination of the original gene takes place and causes reproductive isolation. After the development, of reproductive isolation, the geographically isolated populations may merge again but still they remain distinct. This type of population is known as Sympatric. As they are now reproductively and/or geneitically isolated, they retain their individuality. They have in fact become separate species.

Hence geographical or environmental isolation is the first step in speciation. Finally the reproductive isolation shows formation of new species *i.e.* Speciation.

11.9. Species Concept

Species is the smallest unit of classification The main aim of evolutionary taxonomists is to recognise the basic unit of classification. Taxonomists also try to order the species as realistic a phylogenetic scheme as possible. Taxonomists have used various methods to define species.

Davis and Heywood define species as 'assemblage of individuals with morphological features in common and separable from other such assemblages, by correlated morphological discontinuities in a number of features.' Lumpers tend to combine populations into single species or groups. Splitters tend to combine populations into single species or groups. Splitters tend to separate the same populations into different species or groups.

11.9.1. BIOLOGICAL SPECIES CONCEPT:

Many biologists are not satisfied about the definitions of species which are based primarily on subjective or qualitative morphological characters. Instead, they have

defined a species on biological species concept. According to biological species concept, a species is defined 'as a sexually interbreeding or potentially interbreeding group of individuals separated from other species by the absence of genetic exchange, *i.e.* reproductive isolation.' Members of a sexually reproducing species are capable of mating in nature with one another to produce viable and fertile offsprings but they are unable to breed with members of other apecies. On the basis of morphological characters and interbreedings capacity, species may be of following types, such as *Sibling species* and *Polytypic species*.

(a) Sibling species Two species which are morphologically almost similar but do not normally interbreed are known as sibling species. Example: Drosophila pseudoobscure and Drosophila persimilis, two species of fruit fly which are

morphologically identical, do not cross-fertilise.

(b) Polytypic species—Two species which are morphologically dissimilar and geographically separated but they can interbreed are known as polytypic species. Example: Various species of North American sparrows has been united with the multiple geographical races or sub species of song sparrow (Passarella melodia).

To define a species, the concept of interbreeding can be applied only to the sexually reproducing organisms such as majority animals and most plants. But many species cannot be differentiated only by reproductive isolotion. Although large number of animals and plants are sexual but there are many organisms which are exclusively reproducing asexually; such as all prokaryotes, some fungi and even some higher plants and some animals. In a sexual organism, a species may be defined on the basis of morphological, anatomical and biochemical similarities.

11.9.2. EVOLUTIONARY SPECIES CONCEPT:

Many authors have proposed an 'evolutionary species concept' to overcome some of the problems of biological species concept. In this concept, the species are defined on the basis of differences that are not dependent on reproductive isolation. The supporters of evolutionary species concept emphasised the evolutionary isolation of which reproductive isolation is only one aspect.

George Gaylord Simpsom in 1961 made a statement on evolutionary species concept. According to him, an evolutionary species may be defined 'as a lineage (an ancestor descendant sequence of population) evolving separately from others and with its own unitary evolutionary role and tendencies.' For the first time, this concept incorporates evolution (i.e. change). In this method, he uses morphological, genetical, behavioural and ecological differences. Yet this method also failed to solve all the problems intrinsic to species taxomomy. Because all the traits do not evolve at the same rate or in the same sequence. Hence the drawbacks in species taxonomy are inherent in the process of speciation itself.

11.10. Human Evolution

Man belongs to the family Hominidae of the Primates which includes also ape family. *Proconsul*, one of the oldest fossil indicates a common ancestory of man and ape. This fossil was discovered from South Africa. Near about 25 million years ago it was living on the earth during the Miocene epoch. *Proconsal* bears characters both of man and ape. Hence it indicates the common ancestory of both man and apes. Thus it

is belived that man descended from an ancestor who was common to monkeys and apes. But the story of human evolution as revealed by the fossil evidences is not complete. Yet the fossil evidences so for discovered, will prove beyond doubt that man is a descendent of ape-like ancestors; the modern man like all other animals and plants evolve through changes

11.10.1. FOSSILS OF PREHISTORIC MAN:

1. Australopithecus—This fossil skull is collected from Southern Africa. This fossil skull is showing a combination of ape and human characters. These ape men resemble the apes in cranial size (small) and with man in the structure of the condyles and dentition. In the nature of the palate and pelvis, the ape-man is intermediate between apes and man. The ape man is bipedal. Hence the biologists consider the African pre-man (Australopithecus) as a connecting link between man and the apes. This African pre-man existed to the early part of the Pleistocene epoch and lived between 1000,000 and 500,000 years ago.



AUSTRALOPITHECUS



NEANDERTHAL.



PITHECANTHROPUS



CRO-MAGNON

Fig. 11.2: Showing some fossil men after reconstruction.

2. Pithecanthropus erectus—This is from Java and is commonly know as Java ape-man. The brain capacity is about 900cc which is between great apes and modern

man. Supra-orbital ridges, forehead of skull and face are ape-like but the dentition is man-like and they were erect in posture. The general opinion is that this *Pithecanthropus* was intermediate between *Australopithecus* and modern man. This Java ape-man was existed to the Pleistocene epoch and lived about 500,000 years ago.

- 3. Sinanthropus pekinensis—This fossil was discovered from China and this is commonly known as Peking man. It resembles Pithecanthropus in relation to heavy supra-orbital ridges and a low forehead but the cranial capacity near about 1200 cc. Biologists are of opinion that Pithecanthropus and Sinanthropus were closely related and may be regarded as variants of a single species.
- 4. Homo neanderthalensis—This is commonly known as Neanderthal man. This fossil skull was first discovered from Neanderthal valley in Germany. Later on, this fossil was collected from various places, such as from Europe, Africa and W. Asia. This fossil skull is large with prominent supra-orbital ridges and a receding forchead. The brain was large and the cranial capacity was 1450 cc. The body was slightly stooped and the knees were slightly bent. He lived between 120,000 and 25,000 years ago. After that he became extinct. Neanderthal man knew the manufacture of tools and weapons. Now it is believed that the Neanderthal man descended from the Pithecanthropus as a side line.
- 5. Homo sapiens fossils—This fossil is called the Cro-Magnon man.Large number of skeletons were discovered at Cro-Magnon in France. They were tall, muscular and high browed people. The forehead was high and facial region was reduced to modern man. The cranial capacity was 1700—1800cc. They have developed a high degree of culture and craftmanship. This race was flourished between 50,000 and 20,000 years ago.

11.10.2 EVALUATION OF FOSSILS:

Though the fossil record of man is incomplete yet it is possible to link with one evolutionary stage to another in a natural sequence.

Australopithecus (ape-man) is believed by many biologists to represent an early stage in the human evolution. This is followed by the primitive men of the Pithecanthropus group, such as Pithecanthropus erectus, Sinenthropus pekinensis. The progressive development of the brain in the Pithecanthropus type of early men led to the appearance of Neanderthal type of man. From this point, two separate lines were evolved. In one line, there was continued development of brain, retrogressive changes of limbs, prominent brow ridges along with the specialisation of skull that evolved the Neanderthal man. In another line, there was increased size of brain and brow ridges were reduced; moreover the cranium became rounded with forehead vertical. But the limb bones were primitive in nature This line led to Cro-Magnon man which subsequently evolved to modern man (Homo sapiens). However, it is not known whether the Cro-Magnon man was the direct ancestor of the modern man or just an offshoot of the main branch.

According to recant views all the late Pleistocene men are actually interbreeding natural population. Hence, all the later fossil types are considered to be single species, *Homo sapiens* which is the scientific name of modern man.

11.10.3 FACTORS IN HUMAN EVOLUTION:

The arboreal encestry was most important factor of human evolution. The life on the trees requires two important anatomical changes, such as grasping hand and brinocular vision. So arboreal life requires the modifications of limbs into hands for

the purpose of grasping branches firmly and thus developed the oppossable thumb. Binocular vision was helpful in precisely judging the distance. Arboreal life also requires great powers of balancing and keen sense of hearing.

New and old world monkeys spent the life on trees and thus their descendants became specialised to live on trees. But the ancestors of men and apes gave up tree life and became ground dwellers. The increased competition on the trees and the reduction of forest area due to glaciation during the Pleistocene epoch are the two factors which compelled them to change the habitat.

The line which gave rise to man evolved further to meet the requirements of ground dwelling habits, such as hind limbs became modified for bipedal locomotion with erect posture, perfection of binacular vision, absence of tail. The hands were now free from the job of carrying the weight of the body and could be used for different kinds of work. The most important changes occurred in the cerebral cortex of the brain. As a result, the power of reasoning and memory develop. These capabilities of the prehistoric men gave an advantage to them in natural selection. All these changes in the prehistoric men took place within one million years. Thus there was a rapid change from prehistoric man to modern man

11.10.4 EVOLUTION OF MODERN MAN:

Scientific name of modern man is *Homs sapiens*. Modern man shows very poor structural features. Modern man is not strongly built as in prehistoric man. He has no sharp and pointed teeth; hence there is no effective biting mechanism. He has no efficient protective covering of the body nor he can run fast. The eye sight of the modern man is feeble; hearing power and smell are also poor. In spite of these disadvantages, modern man has been successful because of his ability to conquer his envirorment. He has developed his own culture which is unique in the animal world. The evolution of speech and increase of mental powers pave the path of the development of science and technology in the hand of modern man To day, man is the dominant creature on the earth due to his enormous development of brain along with the science and technologycal development and cultural inheritance.

REVIEW

- 1. Proconsul: This fossil indicates the common ancestory of man and ape .
- 2. Cro-Magnon man: This fossil may be the direct ancestor of the modern man.
- 3. Modern man: In the evolutionary scale, man is the last to appear on this earth.
- 4. Success of man: It is primarily due to the following structural changes -(i) Large size of brain (ii) binocular vision and (iii) erect posture.
- 5. Culture of men: Due to structural changes of modern man, they have developed a culture which is not observed in any other animal. This cultural pattern is also changing.
- 6. Evolution of culture: To day the evolution of man is operating at the cultural level and changes are taking place rapidly.
- 7. Inheritance of experience: Among the animals, only man is capable of utilising the experience of previous generations
- 8. Evolution of man: The evolution of man is divided into two parts, such as evolution of prehistoric man and evolution of modern man.

11.11. Biodiversity

Definition: Biodiversity may be defined as the occurrence of various kinds of organisms in a particular area. Actually the term biodiversity refers to the totality of genes, species and ecosystems of region

Explanation: If you visit to a particular area of forest, you may observe a wide variety of plant life, ranging from a tiny grass to a big tree. You may also observe many varieties of animal life, ranging from a tiny insect to a large mammal. In addition to these there are numerous microorganisms in the soil which you cannot see through your naked eyes. We know that all the species of plants and animals cannot occur at one place. So the biodiversity differs from place to place. Thus there are large number of biodiversity in the living world.

Increasing human population, resource consumption and pollution, these three factors are creating problems to the biodiversity. As a result, biologically rich and unique habitats are destroyed, fragmented and degraded. Loss of biodiversity is now one of the major crisis of the world. How to prevent the loss of species and gene poll is the main challenge to the scientists

We shall study about the biological diversity on earth and the dependence of man on biodiversity for food, medicine and other necessities. We shall also study the activities of man which are affecting biological diversity and causes of increased rate of extinction of speices. We shall mention the various approaches for conserving biological diversity.

11.11.1.MAGNITUDE OF BIODIVERSITY:

Scientific work on identifying and naming of species has been going on for the last 250 years. But we have done it far less number of species than the actual number present on earth.

The total number of species on earth is estimated to range from 5 to 50 million, but only about 1.8 million species so for been described and identified. About 61% of the known species are insects. Only 4650 species of manumals and large number of plant species approximately 2,70,000 are known. So far number of vertebrate species which have been described and identified, are as follows—birds 9700, reptiles 7150, amphibians 4780, fish 26,959. There are many more species which have not yet been collected. Information about bacteria, viruses and protists is just partial. However, new species are being discovered faster than ever before.

11.11.2. TYPES OF BIODIVERSITY:

If we want to develop the conservation plans for biodiversity, we must know about the concept of biodiversity. Biological diversity are of three types, such as—

- (i) Genetic diversity,
- (ii) Species diversity and
- (iii) Community and ecosystem diversity.

All these types of biological diversity are interrelated yet they are distinct enough. So they are to be studied separately so that we can understand the interconnections which support life on earth.

(i) Genetic diversity-

Genetic diversity is said to be the variation of genes within species. These variations could be in alleles, in entire genes or in chromosomal structures. The genetic variation

enables a population to adopt to its environment and to respond to natural selection. Suppose, a species has more genetic variation, it can adopt in a better way in a changed environmental conditions. The speciation or origin of new species depends on the amount of genetic variation. The genetic variation is playing a very important role in the maintenance of diversity at species and community levels. If there are many species then the total genetic diversity will be more of a community. Environmental variability often increases the genetic diversity within a species.

(ii) Species diversity-

Variety of species within a region is known as *species diversity*. Each species is playing a specific role in an ecosystem So, loss of species has profound effect on the ecosystem. The number of species per unit area is known as *species richness*. Generally, greater the species richness, greater is the species diversity. However, number of individuals among the species may also vary, as a result there are differences in equitability and consequently there is diversity. In nature, both the number and kind of species as well as the number of individuals per species vary and consequently lead to greater diversity.

(iii) Community and Ecosystem diversity-

There are three types of diversity in relation to community and ecosystem, such as alpha diversity, beta diversity and gamma diversity.

- (a) Diversity within community is regarded as alpha diversity. It refers to the diversity of organisms in the same community or habitat. A combination of species richness and equitability is used to represent diversity within a community or habitat. When there are changes of habitat or community then there is frequently change of the species.
- (b) Diversity between community is regarded as beta diversity. Here refers to the rate of replacement of species along a gradient of habitats or communities. There are differences in species composition of communities along the environmental gradients like altitudinal, moisture etc. Hence higher the differences in the habitats in a region between communities, higher is the beta diversity.
- (c) Gamma diversity: Diversity of the habitats over the total geographical area is known as gamma diversity.

Ecosystem diversity refers the number of niches, trophic levels and various ecological processes which maintain energy flow, food webs and the recycling of nutrients.

We know that the number of habitats or ecosystems can vary within a geographical area. We also know that savannas, rain forests, deserts, lakes, wetlands and oceans are major ecosystems. In these ecosystems, the species live and evolve. The number of habitats or ecosystems which are present in a region is also a measure of biodiversity.

11.11.3. VARIATIONS OF BIODIVERSITY:

Biodiversity varies with change in altitude or latitude. We have observed that there is a decrease in species diversity from lower to higher altitudes on a mountain. In higher altitudes of a mountain there is a low temperature This low temperature and seasonal variations at higher altitudes are a main factor which reduces diversity.

We also observe the similarity as we move from high to low latitudes (poles to equator) where the biodiversity increases. The climate in the temperate region is severe; so there is short growing period for plants; but in tropical rain forest, the conditions

are favourable for growth throughout the year. Fovourable environmental conditions are helpful for speciation So it is possible for a larger number of species to occur and grow here. The altitudinal and latitudinal variations are two important gradients of species diversity.

11.11.4. BENEFITS OF BIODIVERSITY:

Men derive many benefits directly or indirectly from the living world. Biodiversity is the source of food, medicines, pharmaceutical drugs, fibres and timber. The diversity of organisms also provides many ecological services which are responsible for maintaining healthy ecosystem. The benefits of biodiversity are briefly described below.

(a) In Agriculture—Biological diversity is benefited to modern agriculture in three ways, such as (i) a source of new crops (ii) a source material for breeding improved varieties, and (iii) a source of new biodegradable pesticides.

Wheat, corn and rice are the three major carbohydrate producing crops. These three crops yield nearly two third of the food which is required for human population. Fats, oils, fibres etc. are also utilise by human population and for more production they are searching for new species. Domesticated species which are commercial are crossbred with their wild relatives to improve their traits. In this way, genes of wild species are transferred to domesticated species; as a resut, there will be disease resistant or more yield to the domesticated species.

- (b) In drugs and medicines—Biodiversity is a rich source of substances that are valuable for therapeutic field. Several important drugs have been originated as plant products, such as—Morphine which is produced from a plant (Papaver somniferum) is used as an analgesic; Quinine (From Chinchona ledgeriana) is used for the treatment of malaria. Near about 25% of the drugs are derived from only 120 species of plants. But human populations are using thousands of plant species as traditional medicines.
- (c) As aesthetic and cultural—Biological diversity has also great aesthetic value, such as ecotourism, bird watching, wildlife, gardening etc. From the beginning of human race, they utilise biodiversity through cultural and religions beliefs. Most of the Indian villages and towns, plants like Tulsi (Ocimum sanctum), Pipal (Ficus religiosa) and various other trees are planted; because these are regarded as sacred and they worshipped these plants. Many birds and animals are also regarded as sacred. Plants and animals are regarded as symbols of national pride and cultural heritage.
- (d) Ecosystem benifits—Biodiversity is essential for the maintenance and utilisation of services from ecological systems as well as from the individual species, such as maintenance of gaseous composition of the atmosphere, climate control by forests and oceanic systems, pollination of plants by insects and birds, formation and protection of soil, conservation and purification of water, nutrient cycling etc.

11.11.5. THREATS TO BIODIVERSITY:

There are many factors that causes the extinction of species and consequent of which there is loss of biodiversity. Some of the factors are given below.

(a) Habitat loss and fragmentation—The primary cause for the loss of biodiversity is the destruction of habitats of the organism; such as people when cut down trees, fill a wetland, plough a grass land or burn a forest. In such a situation, the natural habitat of a species is changed or destroyed. As a result, these changes can kill or force out many plants, animals and microorganisms as well as disrupt interactions among the species.

A forest patch surrounded by crop lands or urban areas is an example of fragmented habitats. In such fragmented forest patch, the species which are occupying the deeper part of forests are the first to disapper.

(b) Introduction of exotic species. New species when they are incorporated in a geographical region are known as exotic species. Introduction of such exotic species may change the biotic interactions, as a result they may cause the disappearance of indiginous species. Exotic species are considered as a habitat destruction. Thus they are treated as a major cause of extinction of species. Hence the introduction of exotic species are having large impact in ecosystems.

Extinction of species takes place by theree types of processes, such as Natural extinction, Catastrophes extinction and Man made extinction.

- (i) Natural Extinction—Some species extinct due to change in the environmental conditions and others are more adapted to changed conditions. This loss of species which occurred in the geological past at a slow rate. This type extinction is known as natural extinction.
- (ii) Catastrophes extinction—I arge number of species became extinct in the several perids of earth's geological history—This type of mass extinction of species is caused by catastrophes—This type of extinction of species occurred in millions of years.
- (iii) Man made extinction. Different kinds of human activities are causing the disappearance of large number of species from the earth. This man made mass extinction of species is occurring within a short period of time. Due to this mass depletion of species there is threat to biodiversity.
- (c) Pollution—Pollution is reducing and eliminating populations specially of sensitive species, such as pesticide is causing pollution to water and pollutions are deposited to fish. As a result, tish-eating birds are declined. Another major cause of death is lead poisoning, so depletion of many species. Thus pollution cause the disturbance of biodiversity.

11.11.6. CONSERVATION OF BIODIVERSITY:

We are well aware about the changes of ecosystems. These changes are brought about by pollution, introduction of exotic species, overexploitation by men and climatic change. Biodiversity at all levels is important and needs to be conserved, such as in gene poll, species and biotic community. We should not deprive the future generations from the aesthetic and economic benefits which they can derive from biodiversity.

Conservation of biodiversity is taken on the following strategies

- (a) Protected areas—The areas of land or sea or both are protected for maintenance of biodiversity, such as National Parks and Sanctuaries. Here protection is given to rare species and maintain their scenic beauty and recreational values. Some of the main benefits to protected areas are—(i) maintaining the populations of all indegenous species—(ii) maintaining the number and distribution of communities and their habitats, (iii) conserving their genetic diversity and (iv) preventing introduction of exotic species.
- (b) Reservation of Biosphere It is a special type of protected areas. Here human beings are an integral part of the system. Reservation of biosphere consists of core or natural zone, buffer zone and transition zone.

Absolutely undisturbed protected area is called core zone. Surrounding the core area is the buffer zone. In this area research and educational activities are allowed.

The outermast area of the Bio-phere reserve is called transition zone in this area, activities like settlements of local people cultivation for sir, recreation and other economic uses are allowed inconsultation with the management and local people, so that the conservation is maintained.

The main benefits of biosphere reserves are 100 to 10 m to the conservation of landscapes, econsistents species and econse research are 100 to provide economic development, (iii) to provide research work, educate in and information is change.

(c) Protection of Sacred forests and lakes. The traff common test also to reduce the forest patch (s.d.), to reduce successive these places are free from all disturbances. Thus biodiversity is maintained. Such sacred forests are situated in the different states of India as in Mid-11 into K unataka, Kerala etc. Similarly several lakes in India have been declared sacred by the people. Thus aquatic flora and fauna are protected in these sacred lakes. So biodiversity is protected in these lakes.

11.11.7. HOT SPOTS OF BIODIVERSETY:

In all the geographical regions, biodiversity is not uniformly distributed. Certain geographical regions of the world, there are large number of wild species. These areas are regarded as mega diversity zones.

The concept of hot spots was developed by Norman Micro in 1988. Hot spots are the richest and the most threatened reservoirs of plant and animal are on earth. Hence hot spots are to designate priority areas for conservation. Haoughout the world twenty five terrestrial hot spots for conservation of biodiversity have been identified. Among the twenty five hot spots of the world, two are located in India such as Western Chats and Eastern Himalayas. These areas are rich in flowering plants as well as rich in reptiles, amphibians, butterflies and some manimals and show high legree of endemic species.

11.11.8. INTERNATIONAL EFFORTS FOR CONSERVING BIODIVERSITY

A convention on Biodiversity was held in 1992. The convention recommented three main objectives:

- 1. Conservation of biological diversity.
- 2. Sustainable use of biodiversity and
- 3 Fair and equitable sharing of benefits arising out of the utilisation of genetic resources.

The World Conservation Union (tormerly known as International Union for the Conservation of Nature and Natural Resources ILCN) and the World Wildlife Fund for Nature (WWF) are supporting the projects throughout the world. They are promoting the conservation and development of Biosphere Reserves.

11.11.9. BIODIVERSITY CONSERVATION IN INDIA:

Indian region shows wide biodiversity. India is the centre of diversity of animals and plant species. Indian animals are mithin, buttalo canael chicken, crop plants are rice, sugarcane, banana, fruit plants and vegetables are jack fruit, manoro cucurbity spices and condiments are cardamom, black pepper, ginger, and there are brassicas, bamboos

and cotton tree. In India, conservation of biodiversity is carried out through Biosphere reserves, National Parks, Sanctuaries and protected areas. The tribal people and local communities have access to non-wood forest products and at the same time they protect the forest resources.

The land races and medicinal plants are also being conserved by the tribal people and various non-government agencies. The women are playing a very important role in the conservation of agrobiodiversity.

11.12. Matters to recollect

- The most accepted theory about 'Origin of life' was proposed by Haldane and Oparin.
- Diversities of animals and plants have been evolved through organic evolution.
- History of life is revealed by fossil record.
- Life form is distributed in the different regions on the earth surface.
- Theories of Lamarck, Darwin and de vries are most important in relation to the mechanism of evolution.
- Larmarck's theory is more popularly known as 'Theory of inheritance of acquired characters' which was published in 1809.
- 'Mutation theory' of Hugo de vries was published in 1901.
- Mutation theory postulates that mutations as stated by de vries is the prime factor in the evolutionary processes.
- The main concept of Darwinism is the *Natural Selection* that operates in the speciation. This theory was published in 1859.
- The modern synthesis emphasises the importance of populations as the units of evolution, wherein natural selection play a central role in the formation of new species.
- There are five basic mechanisms that cause variation at the genetic level, such as mutation, recombination, gene migration, genetic drift and natural selection.
- Mimicry is a special kind of protective adaptation serving to ensure better survival of the species. Colouration of living organisms is also one form of adaptation.
- The process by which new species are developed from an existing species is known as speciation. When a single population is separated by different kinds of barrier so that there will be no interbreeding known as isolation.
- Species is the smallest unit of classification. A species in defined as a sexually interbreeding individuals separated from other species by absence of genetic exchange.
- Australopithecus (ape-man) is regarded as an early stage in the human evolution. Then followed the primitive man of the pithecanthropus group. Primitive man led to cro-magnon man which subsequently evolved to modern man (Homo sapiens).
- Various kinds of organisms which are located in a particular area is known as biodiversity. Man is dependent on biodiversity for food, medicine and other necessities.

11.13. Summary

Many theories have been advocated in relation to the origin of life and its diversities. Though the theories of special creation, abiogenesis and catastrophism have some historical importance yet these theories are not accepted due to unscientific explanations. Modern biologists are trying to explain about the origin of life through chemosynthetic theory. Till now the real mystry about origin of life is yet to be discovered. On the other hand, the origin of diversities of organisms has been explored through the theory of organic evolution. Important documental facts have been collected from the study of morphology, embryology and palaeontology of animals and plants. In addition to these, the study of geographical distribution, classification and biochemistry of living organisms also prove that the complex higher organisms have been evolved from the simpler one through the evolutionary processes. Thus it has been proved that the diversities of animals and plants have been appeared on this earth surface due to evolution.

But how or what are the mechanisms by which the various forms of animals and plants appear on this earth? Lamarck, Darwin and de vries, the three renowned biologists tried to explain about the origin of the various forms of animals and plants. Lamarck stated that the characters which have been acquired through the life time of an organism are inherited to the offsprings; this concept is totally rejected by most of the biologists, though it has some historical importance. Darwin's theory of 'natural selection' was published in 1859. Though this theory is not above the creticism yet it is accepted as a revolutionary concept. Mutation theory of De Vries states that the new species arises only through sudden large variations that are heritable. This theory is also an incomplete one about the origin of new species.

Besides the change and diversification of organisms through geological time, there are changes in the hereditary materials. This means evolution occurs at the genetic level. The modern concept of natural selection emphasises the importance of population as the unit of evolution wherein natural selection play a central role in the formation of new species. There are five basic mechanisms that cause variation at the genetic level. So variations are due to mutation, recombiration, gene migration, genetic drift and natural selection. The natural selection is the process of differential reproduction that to differential contribution of genotypes to the gene pool of the next generation. Mimicry and colouration both are protective adaptation that serves as a better survival of the species. Any evolutionary adaptation must have its basis at the genetic level. In the formation of speciation some kind of isolation is necessary and such isolation is geographic or environmental. The species concept also incorporates evolution. Though the fossil record of man is incomplete yet it is possible to link with one evolutionary stage to another in a natural sequence. So the modern man has evolved through evolution.

The biodiversity refers to the totality of genes, species and ecosystems of a region. Increasing human population, resource consumption and pollution—these three factors are creating problems to the biodiversity. National and International efforts are going on for conserving biodiversity.

11.14. Naming/Discovery/Discoverer

- [1] Thales (624-547 B.C): He belived in the spontaneous creation of life.
- [2] Louis Pasteur (1862): He demonstrated that living organisms cannot arise from nonliving substances and so he believed in biogenesis concept.

- [3] Baron George Cuvier (1769-1832): He introduced the theory of Catastrophism.
- [4] I.A. Oparin (1938): Introduced the coacervate model about the evolutionary development of life.
 - [5] Stanley Miller (1953): He proved the idea of Oparin-Haldane theory
- [6] Sydney Fox: Protein coacervates are beheved to have given rise to the first living organisms.
- [7] Jean Bapiste Lamarck (1809): Introduced the theory of inheritance of acquired characters.
 - [8] Charles Darwin (1859): He introduced his 'Natural Selection Theory.'
- [9] Alfred Russel Wallace (1858): He wrote an essay 'On the tendency of varieties to depart indefinitely from the original type.'
- [10] T. Dobzhansky, R.A. Fishar, J. B.S. Haldane, S. Wright, Ernst Mayr and G.L. Stebbins: All these scientists contributed to the modern 'Synthetic theory' on evolution.
 - [11] Hugo de Vries (1901): He proposed the 'mutation theory' on evolution.
- [12] Professor Dart (1925): He discovered a fossil skull which he called Australopithecus showing a combination of ape and human characters.
- [13] Gates (1948): He studied the skull fossils of man and made statement that all the major races of modern man should be considered as belonging to different species. All these species have developed independently.
- [14] Mayr (1950): He made statement that all the late Pleistocene men should be considered of only one species which is known as *Homo sapiens*.
- [15] Leakey (1959): He founds a fossil skull in Tanganyika, East Africa. This fossil skull show resemblances with those of *Homo* and *Pithecanthropus*. He believed that this fossil skull, *zinjanthropus* (African ape man) is the direct line of evolution leading to *Homo* (modern man).
- [16] Norman Myers (1988): The concept of Hot spots in Biodiversity was introduced by Norman Myers.
 - [17] Bates: He for the first time explained the mimicry on scientific point of view.
- [18] Barnard Kettlewell (1958): He made experiment on industrial melanism. He said that industrial areas offer great protection to melanic forms.
- [19] Theodosius **Dobzhansky**: He classified the different types of isolation of the organisms that can lead to the emergence of new species.
- [20] George Gaylord Sinpson (1961): He has given on evolutionary species concept.
- [21] G. H. Hardy and W. Weinberg (1908): They have defined the genetic structure of a non evolving population. This is known as Hardy-Weinberg Equilibrium.

11.15. Answers to Special Questions

- [1] (a) What is organic evolution? (b) How does it differe from chemical evolution? [J.E.E. 1995, '97]
 - Ans. (a) Organic evolution deals with the gradual process of change of one form of life into another and development of new types of living organisms from preexisting types by the accumulation of genetic differences over a long period of time.
 - (b) Chemical evolution is the process of development of complex organic

molecules such as protein, nucleic acids etc. from simple inorganic molecules like methane, amonium, water, hydrogen etc. before the origin of life on earth, where as, organic evolution relates that the present day animals and plants are actually the modified descendants of somewhat different animals and plants which lived in the past.

[2] Why the theory of 'Special creation' was rejected?

Ans. This theory is not based on facts. Moreover palaeontological evidences directly proved that there is a gradual evolution of organisms from ancestors. Hence the theory of Special creation has been rejected by the biologist.

[3] The idea of common descent was suggested by Darwin through his observation on—human pedigrees, comparative anatomy, geographic distribution of species, fossils.

Ans. Geographic distribution of species.

[4] Match the idea associated with the person:

Person	Idea	
Aristotle George Cuvier Oparin Jean Baptiste de Lamarck	(a) Catastrophism (b) Inheritance of acquired characteristics (c) Scala Naturae (d) Mutation theory	
5. Hugo de Vries	(e) Chemosynthesis (f) Natural Selection	

Ans. 1(c), 2(a), 3(e), 4(b), 5(d).

[5] What is micro-evolution?

Ans. Micro-evolution means minute changes that take place through successive generations in an interbreeding population. These small variations gradually accumulate to from large differences of structure Micro-evolution is due to recombination of genes or small mutations.

[6] What is convergent evolution?

Ans. The resemblances between widely diffrent groups of organisms due to common functions or adaptations in a common environment are said to be convergent evolution.

[7] What is adaptive radiation?

Ans. Adaptive radiation shows evolution in several directions starting from a common ancestral type.

[8]. What is parallel evolution?

Ans. Parallel evolution may be defined in which two forms undergo independently similar changes during their evolutionary history. This type of evolution leads to the production of analogous structures which do not indicate close relationship.

[9] Who proposed inheritance of acquired character?

Ans. This theory was proposed by Jean Baptiste Lamarck.

[10] Which era of the geological strata is known as 'age of reptiles'?

Ans. Mesozoic era is regarded as the 'age of reptiles'.

[11] State very briefly how the following names are associated with biological science: (i) H.M.S. Beagle (ii) Galapagos islands. [J.E.E. 1983]

Ans. (i) H.M.S. Beagle: In this ship Charles Darwin made a voyage from

1831 to 1836. During this period he visited many islands of the Atlantic Ocean as well as coasts of South America and also visited Galapagos islands in the South Pacific.

(ii) Galapagos islands: There are large number of small and big islands which are situated on the equator in the pacific Ocean about 600 miles west of South America and these are known as Galapagos islands. A large number of small sized birds called 'Finches' are present in the Galapagos islands and these finches show affinity with the American species. These Finches are of great interest from the evolutionary point as they were one of those animals that influenced Darwin's thinking of evolution.

[12] Mention only the names of the major theories of origin of life. Which one has scientific basis?

(a) Special creation, (b) Spontaneous generation, (c) Catastrophism, (d) Cosmozoic and (e) Chemosynthesis.

Ans. Theory of chemosynthesis has scientific basis.

[13] Write down the name of the elements that are present in the atmosphere of primitive earth.

Ans. Primitive earth's atmosphere consisted of methane, ammonia, hydrogen and water vapour.

[14] What is Coacervate? Who first introduced it?

Ans. Macro-molecules of the primitive ocean were united again one with the other mainly by their force of attraction and form supramolecular structures. The solution of supramolecular structures is known as coacervate. Russian biochemist, A.I. Oparin first introduced this term in 1938.

[15] What is the meaning of evolution? Explain it.

Ans. The word evolution literally means to unfold or to reveal hidden potentialities. Evolution in its broad sense simply means an orderly change from one state to another. The slow and steady changes of organisms over the course of generations are regarded as organic evolution.

[16] In which period of geological time both birds and mammals were evolved? Ans. In the Jurassic period of Mesozoic era both birds and mammals were evolved.

[17] Mention four important animals of the Oriental realm.

Ans. (i) Tiger, (ii) Elephant, (iii) Rhinoceros and (iv) Orangutan.

[18] What is Hardy-Weinberg equilibrium? How this principle helps the geneticists?

Ans. In 1908, G.H. Hardy and W. Weinberg observed that hereditary conservation of genes is the characteristic of a population. This is known as Hardy-Weinberg equilibrium. Geneticists used this principle to calculate allelic frequency at a starting point and then compare it to frequencies measured at some future time. The amount of deviation between observed frequencies and those predicted by Hardy-Weinberg principle indicates the degree of evolutionary change.

[19] What is the raw material of evolution? What are the basic mechanisms of variation at the genetic level?

Ans. Variation among the individuals of a population is the raw material of

(Ans. 11.6.1)

evolution. Variation is caused by mutation, recombination, gene migration, genetic drift and natural selection.

[20] What is speciation? How isolalion helps in speciation?

Ans. The process by which one or more species are formed from an existing species is called speciation.

Isolations particularly geographical isolation is the first step in speciation; because it causes genetic differences between geographically isolated populations; thus it becomes differentiated and give rise to reproductive isolation. As they are now reproductively isolated, they retain their individuality. In fact, they have become separate species.

EXERCISE

• A. I	Essay type /Long Answer type:			
[1]	Write in short about the concept of Haldane and Oparin in relation to the origin of life. (Ans. 11			
[2]				
[3]	Define evolution. Write what you know about the gradual complexities in animal life.			
	· ·	ns. 11.2,11. 3A)		
[4]	Mention the history of life as revealed by the fossil record in the Mesozoic and Cenozo			
		(Ans. 11.4.)		
[5]	Summarise the distribution of life form in space in any four realms.	(Ans. 11.5)		
[6]	Explain in brief the Darwin's theory of natural selection. Mention its demerits.	(Ans. 11.6.1.)		
[7]	What is variation? Write in short the basic processes that cause variation among organ			
		(Ans. 11.6.2)		
[8]	What is microevolution? Narrate the significance of population genetics in evolution.	(Ans. 11.6.2)		
[9]	What is mimicry? Explain mimicry with examples.	(Ans. 11.7.1)		
[10]	What do you mean by colouration of living organisms with examples. Enumerate colura			
	selection.	(Ans. 11.7.2)		
[11]	What is isolation? Describe the different types of isolation. How isolation helps in spe-			
		(Ans. 11.8)		
[12]	Write an essay on the concept of species.	(Ans. 11.9)		
[13]	Write in brief the fossils of prehistoric man. What are the factors that cause human evo			
	· ·	1.10.1, 11.10.3)		
[14]	7,1111111111111111111111111111111111111	11.11, 11.11.2)		
[15]	Describe the benefits of biodiversity.			
[16]	What are the factors that causes the loss of biodiversity? Describe them in short.	(Ans. 11.11.5)		
[17]	Describe the conservation of biodiversity.	(Ans. 11.11.6)		
[18]	What is 'hot spot' of biodiversity? What are the efforts that conserve biodiversity in India?			
	· ·	1.11.7, 11. 11.9)		
	Short Answer type:			
[1]	Who's view is the 'survival of the fittest'?	(Ans. 11.6.1)		
[2]	What do you understand by 'prodigality of production?	(Ans. 11.6.1)		
[3]	What is survival of the fittest?	(Ans. 11.6.1)		
[4]	Who put forward 'Theory of natural selection'?	(Ans. 11.6.1)		
[5]	What is 'theory of Spontaneous generation'?	(Ans. 11.1.2)		
[6]	Mention the chemical composition which was present in the primitive atmosphere.	(Ans. 11.1.5)		
[7]	What is the role of gene flow in evolution?	(Ans. 11.6.2)		
[8]	What is genetic drift?	(Ans. 11.6.2)		
[9]	What is sabilising selection?	(Ans. 11.6.2)		
[10]	Write in brief about reproductive isolation.	(Ans. 11.8)		
●C. D	istinguish between:			
[1]	Inorganic evolution and Organic evolution.	(Ans. 11.15)		
[2]	Special creation and Spontaneous generation.	(Ans. 11.1)		
4	Obories croation and obortempora Paristerant			

Intraspecific struggle and Interspecific struggle.

[3]

	44.60
[4]	Macroevolution and Microevolution. (18) (Ans. 11.6.2)
[5]	Gene migration and Genetic drift.
[6]	Directional selection and Disruptive selection (Ans. 11.6.2) (Ans. 11.7.1)
[7]	Mimic and Model
[8]	(Ans. 11.8)
191	Sibling species and Polytypic species. (Ans. 11-2)
1101	Beta diversity and Gamma diversity. (Ans. 11.11.2)
	White Chart nates
[1]	Cormercus theory (Ans. 11.1.4) [2] Concervate model (Ans. 11.1.5) [3] Survival of the fittest (Ans.
1.1	11.6.13 [4] Hardy-Weinberg equilibrium (Ans. 11.6.2.) [5] Genetic drift (Ans. 11.6.2) [6] industrial
	melanism. (Ans. 11.7.2) [7] Hybrid sterility (Ans. 11.8) [8] Evolutionary species concept (Ans. 11.2)
	[9] Sinanthropus pekinensis (Ans. 11.10) [10] Variations of biodiversity (Ans. 11.11.3)
●£.	But of mark an correct enswer on the narenthesis:
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[11	water carbon)
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1-1	Dortour
[3]	
[2]	Urea and nucleic acid: Amino acid and protein)
[4]	For origin of life, most important condition is, the presence of (Oxygen, carbon, water, Nitrogen)
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10	ammonia, methane and water vapours. Ammonia, methane and oxygen.)
16	and the design of Danier C Damein S Miller Holdone and
10	Oparia)
17	and was cettled in India was (A. I.
1,	Oparin, L. Pasteur, J. Huxley, J.B.S. Haldane)
[8]	D. Language D. Language Co. D. Continuoro and D.
	Fill in the blanks with correct word:
[1	and the state of t
[2	The second secon
13	I was a second to the second that
14	suggested his coacervate model.
15	Sudden heritable change in the characteristic of the organism is caused by
[6	1 Sometimes a population is separated by some———barrier and thus prevented from ——
j7	
	National Action Control of the Contr
•G	. Put ✓ mark on Yes or No for the statement:
[1	Baron George Cuvier putforth a theory of Catastrophism——Yes/No
[2	Theory of Chemosynthesis about origin of life was advocated by Charles Darwin Yes/No
13	Coacervate model in relation to Origin of life was introduced by Sydney Fox — Yes/No
14	Ethiopian realm consists of Africa, Soudi Arabia and Madagascar—Yes/No
[5	Evolution on the grand scale of geological time is known as microevolution— Yes No
16	The differences of Characteristies between members of the same species are called variation — Yes/No

- Answer to Q. number of E, F and G -

E. [1] Oxygen [2] L. Pasteur [3] Proteins and nucleic acids [4] Water [5] Hydrogen, ammonia, methane and water vapours [6] Haldane and Oparin [7] J. B. S. Haldane [8] Mesozoic.

F. [1] Six [2] Lamarck [3] Charles Darwin [4] Oparin [5] mutation [6] geographical, interbreeding [7] sibling species.

G.[1] Yes [2] No [3] No [4] Yes [5] No [6] Yes.

Population Biology

Topics Discussed: Introduction, Population growth, Human population growth, Overpopulation (causes and effects), Mental health, Tobacco smoking and chewing, Alcohol & alcoholism, Drug addiction; Global immunization (Pulse polio)

12.1. Introduction: What is Population?

The term population is derived from the Latin word 'populus' meaning 'people', and it was originally used to denote a group of people occupying a particular area. However, the term population is now applied in broader sense for all living organisms. A population is defined as a group individuals (living organisms) of a species living within a specified habitat. For example-all mango trees of the same species occurring in a particular area constitute a population. The tigers of the same species present in a forest represent a population. Similarly, a group of bacteria present in a pond also constitute a population.

In natural conditions, populations of different species of plants, animals and microorganisms live together—within the same habitat. All such populations collectively constitute the **biotic community** of the habitat. The term population is interpreted differently in different fields of biology. In **ecology**, a population means a group of organisms of the same species living in the same habitat and functioning as a unit of biotic community. In **genetics**, a population is a group of interbreeding individuals of the same species which is isolated from other groups. In **human biology**, a population is a group of human beings living in a given area like a particular village, town, state, country or even the whole world.

12.1.1. POPULATION SIZE AND POPULATION DENSITY

Population size means the total number of individuals in a population. The size of a population is represented by its **density** (i.e. population density) which means the number of individuals present per unit area or volume of the habitat e.g. number of human inhabitants per km² or number of a tree species per hectare or number of diatoms per cubic meter of sea water etc. Population density is an important index for comparing different populations. The density of population of certain species may vary from time to time (i.e. seasonally) and from one place to another.

12.1.2. POPULATION CHARACTERISTICS

A population has a number of characteristics which are the properties of the whole group and not of the individuals. These are density, natality (birth rate) mortality (death rate), age distribution (ratio of different age groups), biotic potential (the maximum possible rate of reproduction of a species i.e. its ability to increase in number under optimal conditions), dispersal (migration—of individuals into or out of the population), and growth form (pattern of change of population size with time).

12.2. Population Growth

'Population growth' means increase in population size (i.e. number of individuals in a population) over a period of time. It is determined by the number of births, deaths, immigrations and emigrations in the population, and is given by the following equation

$$PG = (P + B + I) - (D + E)$$

where, PG=population growth, P=initial population size, B=number of births, I=number of immigrations (individuals coming in), D=number of deaths and E=number of emigrations (individuals moving out).

12.2.1. POPULATION GROWTH FORMS AND POPULATION GROWTH CURVES:

The nature or characteristic pattern of population growth in relation to time is called **population growth form** which is generally represented graphically by plotting population sizes at time intervals. Such graphs are called **population growth curves**. There are two basic population growth forms that are represented by **J-shaped growth curve** and **S-shaped** (or sigmoid) **growth curve**.

The J-shaped growth curve (Fig. 12.1.a) describes a growth form in which there is an initial phase of slow population growth (lag phase or establishment phase) during which the population adapts to the new environmental conditions and establishes itself. Then the population grows very rapidly and continues to grow exponentially (or geometrically, i.e. $2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32$ and so on) until the growth is stopped abruptly and the population is crashed. The exponential growth phase continues as long as the environment can support the growth by providing food and other resources required for multiplication of the individuals. The final crash may be triggered by factors such as change of season (or end of breeding phase), limitations of food supply etc. The J-shaped growth form is observed in case of many insect populations which show an explosive increase in number during a particular season followed by their disappearance at the end of the season. This type of population growth is said to be density independent because growth rate is not affected by the population density until the final crash.

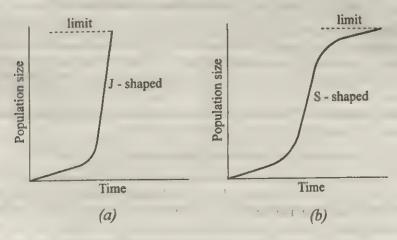


Fig. 12.1: J-shaped and S-shaped growth curves.

The S-shaped or sigmoid growth curve (Fig.12.1.b) has three phases—an initial phase of slow growth (lag phase), a middle phase of rapid or geometric growth

(exponential phase) and a last phase of zero growth (stationary phase). It represents a growth form in which the population size increases very slowly at the beginning because at that time, there is a shortage of reproducing individuals, and the population requires some time to adapt and establish itself to the new conditions. Once the population is adapted, it multiplies rapidly because of the plentiful availability of food and other requirements of life. Then the population growth begins to decline due to increasing environmental resistance (unavailability of food etc) and finally the growth rate becomes nearly zero so that the population size remains more or less constant. At this phase, birth rate and death rate balance each other resulting in equilibrium. This type of population growth is said to be density dependent because for a given set of resources, growth rate depends on the number of individuals present in the population. The maximum population size of an organism that can be supported by a given environment is called the maximum carrying capacity of the environment, which is represented by the point of stabilization or zero growth rate. Majority of the living organisms including micro-organisms, plants and animals show the sigmoid type of population growth form.

12.2.2. FACTORS AFFECTING POPULATION GROWTH

The study of how and why a population size changes over a period of time is called **population dynamics** which requires study of group properties of the population (mentioned earlier), interaction between different populations (e.g. predation, competition, parasitism etc.) and environmental factors (e.g. availability of resources like food, water and oxygen, climatic conditions, pollution etc). The size, density and growth of a population depends on several factors, which are as follows:—

- [1] Birth rate or natality—It refers to the rate at which new individuals are added to the population by reproduction, i.e. number of individuals born per unit time. Thus, population growth has a direct relationship with the birth rate. Higher the birth rate, greater the size (or growth) of the population provided other factors remain unaltered.
- [2] Death rate or mortality—It is the rate at which individuals are lost by death from a population, i.e. number of individuals dying per unit time. The size and growth of a population is inversely related to its mortality.
- [3] Dispersion or migration—It refers to movement of individuals from one place (habitat) to another. New individuals may move into a population (immigration) to increase its size or some individuals may move out of a population (emigration) to reduce its size. Migrations may occur within a country from one region to another or from one country to another. Population growth is proportional to net immigration (i.e. immigration emigration).
- [4] Age and sex composition—Age composition of a population refers to the proportion of individuals of different age groups in the population. Populations with more young members grow rapidly, while declining populations have a large proportion of older members.

Sex composition or the proportion of reproductively active males and females in a population also influences the population growth because the birth rate is influenced by the number of reproductively active female individuals present in the population.

[5] Biotic potential, environmental resistance and maximum carrying capacity— The inherent maximum capacity of a species to reproduce and increase in number under optimal conditions is termed as biotic potential. It can be expressed only when the environmental conditions are non-limiting so that the individuals are allowed to reproduce freely. Under such conditions, the natality rate is maximum and mortality rate is minimum, and the population grows at a maximum rate. However, nature does not allow this indefinitely and keeps a check on the expression of biotic potential.

The tendency of the environment to restrict the population size or its biotic potential is called environmental resistance. It is due to various factors such as —(i) shortage of food, water, oxygen, space (shelter) etc., (ii) presence of predators, parasites and diseases, (iii) accumulation of toxic wastes and (iv) adverse climatic conditions. The environmental resistance against a population usually increases with the increase in size of that population. This is why a species cannot attain its biotic potential under natural conditions. Otherwise, the earth will not be able to accommodate so many living species within a few years.

The resultant of biotic potential and environmental resistance is expressed by the term maximum carrying capacity of a given environment for a species. It is defined as the maximum number of individuals of a species that can be supported by a given environment. Less the environmental resistance, more is the carrying capacity and greater is the possibility of population growth.

12.3. Human Population Growth

The scientific (statistical) study of human population is called **demography**. It is based on reports of census. Census is the process of counting of human population of a country at regular intervals taking in account the area-wise distribution, age and sex composition as well as the social, economic and health status of the people. In most countries, it is carried out at an interval of ten years. Census reports and demography have revealed that human population is growing (i.e. increasing in size) day by day. The pace of human population growth is measured by two important parameters—annual average growth rate and doubling time.

The annual average growth rate means the average yearly increase of population size expressed as percentage of previous year's population size.

It is calculated as follows:-

Annual average growth rate (per cent)=
$$\left(\frac{P_2 - P_1}{P_1 \times N}\right) \times 100$$

where P_2 =Population size of present census, P_1 =Population size of previous census and N=number of years between the two census.

The **doubling time** is the time required for a given size of population to double itself. It decreases with the increase in annual average growth rate and vice versa.

12.3.1. TRENDS OF HUMAN POPULATION IN THE WORLD

Human beings appeared on earth about fifty thousand years ago. Initially, the human population was small and it grew very slowly. At the beginning of the Christian era, the world population was around 250 million and it increased to about 400 million by the year 1650. Thereafter the pace of population growth has accelerated greatly. Table 12.1 shows the trends of world population growth since the year 1800.

Table-12.1: World population.

Year	Population size (million)	Annual average growth rate (per cent)
1800	978	
1850	1262	0.5
1900	1650	0.6
1950	2526	1.1
1960	3037	1.79
1970	3696	1.92
1975	4066	1.89
1980	4432	1.72
1987	5000	1.63
1991	5385	1.7
2000	6054	1.4

The world population was nearly I billion (1000 million) in the year 1800, then it crossed 2 billion in 1930, 3 billion in 1960, 4 billion in 1975, 5 billion 1987 and 6 billion in 2000. Thus, the population has increased from 1 billion to 2 billion in 130 years and then from 2 billion to 4 billion in only 45 years indicating a decline in doubling time. The annual average growth rate of world population has gradually increased and attained a peak value of 1.92% around 1970. Since then, it has declined slightly to 1.4% in 2000 due to implementation of family planning programmes, particularly in the developed countries. World Population is currently increasing at the rate of over 253 thousand people per day and over 92 million per year. The growth rate is not uniform in the world; it is much less in developed countries (e.g. in Europe it is 0.5% per year) but very high in developing countries (1.9% per year in Asia). At present about three fourths of the world's population lives in developing countries that are facing pressure on land, food, water, health, education and employment.

12.3.2. TRENDS OF HUMAN POPULATION IN INDIA

India is the second most populous country in the world, next to China, whereas seventh in land area. With only 2.4% of the total land area of the world, India is supporting over 16% of the world's population. In comparison to U.S.A., the land area of India is nearly half but the population is more than three times. The decadal Population of India since 1901 is shown in Table—12.2.

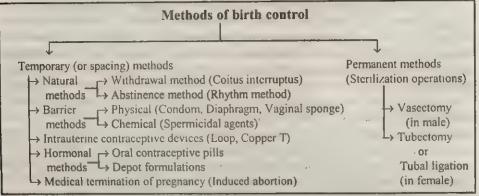
Table 12.2: Population in India (1901-2001)

Year	Population size (million)	Annual average growth rate (%)	Population density (persons/km²)
1901	238		77
1911	252	0.56	82
1921	251	(-)0.03	81
1931	279	1.04	90 ·
1941	318	1.33	103
1951	361	1.25	117
1961	439	1.96	142
1971	548	2.20	177
1981	683	2.22	216
1991	843	2.14	267
2001	1027	1.93	324

India's population has been steadily increasing since 1921. The annual average growth rate as well as population density has increased tremendously. The population of India is currently increasing at the rate of 16 million per year. In 1901, India's population was 238 million which doubled in about 60 years (in 1961) to 439 million which doubled again in only 30 years (in 1991) to reach 846 million. However, it is consoling to note that in spite an increase in population size, the growth rate is slightly declining since 1981. This suggests that promoting birth control measures are having some effect. But the current growth rate of 1.93% per year is still very high and it has to be checked further for a better socio-economic development of our country.

12.4. Population control

Population control means control of birth rate and family planning for checking overpopulation (excessive growth of human population). Common methods of birth control are shown in the following chart and described in brief.



- A. Temporary methods: These methods are reversible *i.e.* effective so long as used and can be discontinued when the couple desires to have a child. These are used as spacing methods to delay the first issue or to prolong the interval between births. Temporary methods may be of various kinds.
- [1] Natural methods: These are very common and simple methods based on controlling the act of coitus, requiring no artificial means, but their failure rates are very high. There are two such methods:
- (i) Withdrawal method (or coitus interruptus)—In this, during coitus (or sexual intercourse), the penis is withdrawn from vagina just before ejaculation so that semen is not deposited into the vagina.
- (ii) Abstinence method—In this, coitus is to be avoided during the fertile phase of menstural cycle (i.e. around ovulation) which extends roughly from 8th to 21st day of the cycle. It is also called rhythm method or calender method or safe period method. Its reliability can be increased by daily monitoring of body temperature (noting the ovulatory rise of body temperature) and cervical mucus study (at the time of ovulation, the cervical mucus becomes more slippery, clear and watery) to detect the time of ovulation.
- [2] Barrier methods: The basis of this method is to prevent live sperms from reaching the ovum by placing some physical or chemical barriers along the path of the sperms before every intercourse.

(i) Physical barriers—They include condom for men and diaphragm (or cervical cap) and vaginal sponge for women. Condom is a thin but strong rubber sheath used to cover the erect penis to prevent deposition of semen in vagina. Diaphragm (cervical cap) and vaginal sponge made up of synthetic material are inserted into vagina to cover the cervix so that sperms cannot enter into the uterus. Condoms and diaphragms also give protection against sexually transmitted diseases including AIDS.

(ii) Chemical barriers—These are spermicidal agents available in various forms e.g. foam tablets, jellies, pastes, creams, suppositories and soluble films that are introduced into vagina before coitus to kill or mactivate the sperms so that they cannot enter into the uterus. When a physical or chemical barrier is used alone, its failure rate

is very high but if they are used in combination, they become very effective.

[3] Intra uterine contraceptive devices (IUCDs or IUDs): IUCDs are small objects that are inserted into the uterus through vagina by a physician to prevent migration of sperms and/or implantation of the fertilized egg. They include non-medicated (biologically inert) plastic materials called loop (Lippes loop) and medicated (bioactive) materials like copper T or steroid releasing devices. IUCD has many advantages—it is cheap, its insertion is a simple procedure and one time insertion gives continuous protection for a long period (upto serveral years), it is very effective (i.e. failure rate is low) and it can be easily removed when desired.

[4] Hormonal methods: These methods involve administration of synthetic female sex hormones (estrogen and progesterone) to a woman to prevent pregnancy. Various hormonal contraceptives are now available which differ in composition and mode and schedule of administration. They act by preventing ovulation and also by causing thickening of cervical mucus (which prevents entry of sperms into the uterus) and endometrial changes (that prevent implantation in the rare event of fertilization). Hormonal contraceptives are very effective but they may produce some side effects. They are broadly of two types:

(i) Oral pills-They include combined pills, progesterone only pills (POP) or minipills and morning after pills. Combined pills and minipills are to be taken regularly and strictly according to their monthly schedule. Morning after pills are post-coital contraceptives mainly used following rape, unprotected coitus or accidental rupture of

condom during coitus taking place around ovulation.

(ii) Depot formulations—These are long acting (slow release), estrogen free preparations containing progesterone, a single administration of which is sufficient to prevent pregnancy for several months or years. They are available in the form of

injectables, subdermal implants and vaginal rings.

[5] Medical termination of pregnancy (MTP): This is a post-conceptional method of birth control commonly known as induced abortion. In this, pregnancy is deliberately terminated under proper medical supervision before complete development of the foetus. It can be done chemically (by administration of drugs) or surgically (by suction of uterine contents). Earlier MTP was illegal but now it has been legalised in many countries including India. Although many people consider MTP as unethical and it has some risks, it is often used as the last resort to avoid unwanted child birth when a woman has already become pregnant due to failure of other contraceptive measures or rape.

B. Permanent methods: These are irreversible and one-time methods of birth control involving sterilization of male or female by minor surgical operations interrupting the normal path of transport of sperm or ovum. Male and female sterilization operations are known as vasectomy and tubectomy (or tubal ligation) respectively in which a

segment of vas deferens or fallopian tube of each side is excised and removed and the cut ends are ligated. Vasectomy is simpler, safer and cheaper than tubectomy. Such operations are recommended for those couples who desire no more children and have at least two living children.

Besides birth control measures, two other factors are also important for population control:

- (i) Age of marriage—Raising the age of marriage will reduce the reproductive span and help in population control. So, child marriage, which is very common in our country, should be discouraged. In our country, there is a 'Child marriage restraint act' according to which the lower age limit of marriage is 18 years for girls and 21 years for boys. Moreover, it has been suggested that a woman below 20 years of age is not physically and mentally grown enough for motherhood.
- (ii) Mass awareness For population control, mass awareness about the evils of overpopulation and the responsibility of every couple to limit their family size is necessary. The government should launch programmes to motivate people by mass campaign through radio, television, newspapers, magazines, posters etc., and by providing low cost or free family planning sevices through hospitals and health centres.

REVISON

Population—A group of living organisms of the same species occupying a particular space.

Population size—Total number of individuals in a population.

Population density—Population size per unit area or volume of the habitat.

Population growth—Increase in population size over a period of time.

Biotic potential—The maximum capacity of a species to reproduce under optimal conditions.

Maximum carrying capacity—The maximum population size that can be supported by a given environment.

Demography—The statistical study of human population.

12.5. Mental Health

- **Definition**: Mental health is the balanced development of an individual's personality and emotional attitudes which enable him to live in harmony with others and to face and accept the realities of life.
- Characteristics of a mentally healthy person: A mentally healthy person has three main characteristics:
- [1] Feeling comfortable about self i.e. feeling of security, proper self-estimation (neither underestimates nor overestimates own ability), ability to accept own shortcomings, having self-respect etc.
- [2] Right feeling towards others i.e. ability to take interest in others, to love them, to take their responsibility and to trust them.
- [3] Ability to meet the demands of life i.e. ability to tackle a problem, to take correct decisions, to set reasonable goals for himself and not to be bowled over by his own emotions of fear, anger, love or guilt.

12.5.1.MENTAL ILLNESS

Impairment of mental health is referred to as mental illness. The body and mind are intimately related to each other and disturbance in one hinders normal functioning of the other. So, mental health is important for maintenance of physiological health. It has been estimated that about 1% of the world population is suffering from serious mental illness and 16% from mild mental disorder. The case of mental illness is increasing day by day due to the tremendously increasing socio-economic pressure that a man has to encounter.

12.5.1.A. CHARACTERISTIC FEATURES (OR SYMPTOMS) OF MENTAL ILLNESS

Mental illness is characterised by the following symptoms:—[1] insomnia (lack of sleep) or excessive sleeping, [2] depression and feeling of hopelessness, [3] unreasonable phobias (fears), [4] delusions (false beliefs) and hallucinations (sensory impressions in absence of stimulations), [5] partial or complete loss of memory and lack of thinking ability, [6] compulsive actions and violent behaviour, [7] self-destructive behaviours (e.g. gambling, drinking, drug abuse etc.) and thoughts of suicide, and [8] desire to remain isolated from other people.

These symptoms cause disturbance in the individual's day to day activities and his or her relationship with others does not remain normal.

12.5.1.B. TYPES OF MENTAL ILLNESS

Mental illnesses are broadly grouped into two classes—[1] major (or severe type of) mental illnesses and [2] minor (or mild type of) mental illnesses, each class having some sub-types.

- [1] Major mental illnesses: The major mental illnesses are called psychoses (singular-psychosis) in which the victim is 'insane' (mad) and out of touch with the realities of life. They are usually not aware of their illness and do not like to take any treatment. There are three types of major mental illnesses:
- [a] Schizophrenia—In this, the patient lives in a dream world of his own, often laughing or crying at inappropriate situations. Schizophrenics suffer from disturbed emotions (showing rapidly shifting extreme responses), delusions, auditory hallucinations etc.
- [b] Manic depressive psychoses or mood disorders—In this type of mental illness, the victim shows occasional bouts of elation (emotional excitement) and depression (sadness, hopelessness, lack of self confidence etc.).
- [c] Paranoia—It is associated with undue and extreme suspicion and tendency to regard the whole world in a framework of delusions.
 - [2] Minor mental illnesses: These are of two types:
- [a] Neurosis or psychoneurosis—It is a mal-adaptive mental disorder in which the patient is not out of touch with reality but is unable to react normally to different situations of life. Such patients are not considered as 'insane' by their fellow-men but they extibit certain peculiar symptoms like fear of disease, anxiety, vague aches and pains, compulsions (being compelled to perform an act despite their own attempt to resist it) and obsessions (constant doubts). Unlike psychotics, the neurotics are fully aware of their illness and they seek treatment.

[b] Personality and character disorders—These are due to unfortunate experiences of childhood and characterised by unpredictable moods, outbursts of emotional reactions, quarrelsome behaviour and conflicts with others.

12.5.1.C. CAUSES OF MENTAL ILLNESS

Mental illness may be caused by either a single factor or multiple factors of the following:—

- [1] Changes in brain—The brain controls all the behavioural activities of a man. Any adverse change in the structure and function of brain may cause mental illness. Such changes in brain may occur due to injury by accidents, infections, tumors, poor blood supply, intake of toxic substances (e.g. alcohol and certain drugs), nutritional deficiencies (e.g. deficiency of some vitamins and iodine) and some degenerative diseases (e.g. tuberculesis, leprosy, epilepsy etc.).
- [2] Childhood experience and family atmosphere—For development of normal mental health, a child requires love, affection, encouragement, guidance and discipline. A person deprived of these things and subjected to repeated unpleasant experiences in childhood may develop mental illness. Thus, a child growing in a good, accommodative and affectionate family atmosphere develops a pleasing personality and behaviour and can adjust to different situations of life. Whereas, if there is always quarrels and unpleasant atmosphere in a family, the children may develop mental illness.
- [3] Heredity—Heredity may be an important factor for mental illness in some cases. It has been observed that the child whose both the parents are schizophrenic is more likely to develop schizophrenia than the child of mentally healthy parents. However, the mental illness of the parents may or may not be expressed in their children.
- [4] Socio-econmic factors—Several socio-economic factors may also be responsible for mental illness. They include poverty, worries, anxieties, stress, tension, frustration injustice, insecurity, cruelty, unhappy marriages, change in family structure, etc.

12.5.1.D. TREATMENT OF MENTAL ILLNESS:

Mental patients usually require long-term treatments and care. Many of the mental illnesses are not completely cured for ever, rather they are kept suppressed by continuous treatment. Treatments for mental illnesses are of following types:

- [1] Shock treatment or electroshock therapy—In this, electric current (or shock) is passed through the brain of the patient to induce convulsions. It is also called electroconvulsive therapy. It brings dramatic improvement in selected cases of mental illnesses, particulary in severe depression.
- [2] Psychotropic drug therapy—Chemical agents used as medicines for treatment of mental disorders are called psychotropic drugs. These medicines help to maintain a proper balance of brain nurotransmitters for normal functioning of the brain. Various antipsychotic, antianxiety, antidepressant and antimanic drugs are now available to treat mental patients.
- [3] Psychological treatment or psychotherapy—It involves counselling of the patients by trained personnel to increase their mental strength, so that they can adjust well to different situations of life.
- [4] Social therapy and rehabilitation—The family members and fellow beings of a mentally ill person have the responsibility in rehabilitation (restoring good condition) of the patient. The patient should be tackled sympathetically and given proper attention,

treatment, encouragement; education, training and oppertunity to work. Social therapy and rehabilitation play a significant role in improving the conditions of such patients.

REVISION

Mental health—A balanced mental development which enables a person to adjust with the society and to face and accept the realities of life.

Psychosis—The major mental illness or insanity (madness) in which the patient is out of touch with the realities of life.

Scizophrenia—A psychotic condition in which the patient lives in his own dream world.

Depression—A mental state of sadness and hopelessness.

Elation—A state of being in high spirits or mental excitement.

Neurosis—A minor mental illness in which the patient cannot react normally (or adjust) to different situations of life.

12.6. Tobacco Smoking and Chewing

Tobacco is the dried leaves of the plants *Nicotiana tabacum* and *Nicotiana rustica*. It is used world-wide mainly in the form of **smoking** cigarettes, bidis, pipes or cigars. Large number of people also **chew** tobacco in betels in many countries including India.

The chief toxic material present in tobacco is an alkaloid called nicotine, which is responsible for addiction to tobacco. In addition to nicotine, tobacco smoke also contains certam other toxic materials like carbon monoxide (CO) gas and some polycyclic aromatic hydrocarbons e.g. benzopyrene, tar etc.

12.6.1. TOBACCO ADDICTION AND ITS CAUSATIVE FACTORS

Habit of smoking or chewing tobacco develops mainly in adolescence. Teen agers usually start smoking or chewing tobacco just for curiosity or fashion or to show off adulthood. Young people are generally induced to consume tobacco by three factors—[1] being persuaded and pressurised by friends, [2] following the examples of elders and parents, and [3] employment outside the home. Regular smoking or chewing habit leads to tobacco addiction (i.e. dependence on nicotine), when the person becomes slave to it and cannot keep mentally and physically well without consuming tobacco.

12.6.2. HARMFUL EFFECTS OF TOBACCO ADDICTION

Nicotine is a stimulant but highly poisonous substance. Some people believe that smoking provides a temporary relief during the states of stress and strain but it has been proved that regular consumption of tobacco is definitely injurious to health. Both smoking and chewing of tobacco are harmful of which smoking is more dangerous because of two reasons—(a) tobacco smoke contains some additional toxic materials other than nicotine as mentioned earlier, and (b) smoking not only harms the smoker but also affects others who passively inhale the smoke. Consumption of tobacco causes harm to more or less all the body systems, of which the respiratory and circulatory systems are worst affected. The hazards of tobacco consumption are as follows:—

[1] Respiratory disorders—As tobacco is used mainly in the form of smoking in which the smoke of tobacco is inhaled, it first attacks the respiratory system causing irritation to larynx, respiratory tract and lungs. Smokers usually suffer from cough,

phlegm production and shortness of breath on exertion. Tobacco addiction in the long run also produces severe and life-threatening diseases like chronic bronchitis, emphysema, asthma and chronic obstructive pulmonary disease (COPD). In addition to the above mentioned effects of nicotine, the carbon monoxide present in tobacco smoke also impairs respiration because it combines with haemoglobin and reduces the oxygen carrying capacity of blood. Nicotine as well as polycyclic aromatic hydrocarbons of tobacco smoke are highly carcinogenic; so heavy smokers often develop cancer in throat (larynx) and lungs.

[2] Cardiovascular disorders—Nicotine increases heart rate and blood pressure and also the risk of coronary heart disease (CHD), atherosclerosis, myocardial infarction, angina (chest pain) and stroke. Heavy smoking is a major cause of

premature deaths due to coronary heart disease.

[3] Gastro-intestinal disorders—Nicotine adversely affects the functioning of gastro-intestinal system. Tobacco addiction (both smoking and chewing) may produce gastric and duodenal ulcers.

[4] Endocrine and reproductive disordrs—Consumption of tobacco (nicotine) may produce certain endocrine disorders by altering the secretion of some hormones. It increases secretion of adrenaline, ACTH, corticoids etc. which inhibits gonadotrophin secretion.

Nicotine also produces some reproductive disorders e.g. menstrual irregularity, early menopause and ovarian cyst in females and sterility in males due to decrease in sperm production. In pregnant women, nicotine causes in retardation of foetal growth and development. Consumption of tobacco during pregnancy often leads to **premature** births or birth of underweight babies or even still-birth.

- [5] Malignancy—As mentioned earlier, both nicotine and polycyclic aromatic hydrocarbons are carcinogenic. Heavy consumption of tobacco for a long time not only leads to lung and throat cancer but may also produce cancer in mouth, oesophagus, urinary bladder, pancreas, uterus *etc.* Particularly the tobacco chewers are more prone to oral cancer.
- [6] Social hazards—Tobacco addiction has some other harmful eflents that are not life-threatening but adversely affect the human society. These are—(a) It is an expensive habit. (b) It is often annoying to other people. (c) It stains the teeth and fingers. (d) It makes the breath unpleasant. (e) Smokers often throw burning cigarettes or bidis here and there, which may be responsible for spreading of fire. (f) Tobacco chewers often spit here and there causing a public nuisance. Use of tobacco is responsible for large number of middle age deaths due to cardio-respiratory diseases and malignancy.

Surveys have revealed that consumption of tobacco is decreasing in developed countries because of health consciousness among the people. In contrast, use of tobacco is rising in developing countries among both men and women due to their unawareness and misjudgement regarding the hazards of long term tobacco consumption.

12.6.3. HOW TO STOP TOBACCO ADDICTION?

People should be informed and warned about the risks of using tobacco so that they do not start this bad practice and those who have already started, can give up the habit. If a tobacco addict gives up the habit of smoking or chewing, he or she may experience some withdrawal symptoms such as irritability, anxiety, headache, sleep problems,

lethargy etc. However, these symptoms do not last for more than a few weeks; thus a person having self confidence can easily give up the habit of using tobacco.

12.7. Alcohols and Alcoholism

Alcohols are hydroxyderivatives of hydrocarbon compounds that are found in the form of volatile liquids. There are different types of alcohols *e.g.* ethyl alcohol (or ethanol), methyl alcohol (or methanol), isopropyl alcohol *etc.* that are used for different purposes. When unspecified, the term 'alcohol' refers to ethanol. Ethanol is the type of alcohol used for human consumption in the form of various alcoholic beverages like beer, wine, whisky, brandy, rum, gin, vodka *etc.* These beverages differ in taste, flavour and alcohol (ethanol) content. Ethanol is also used in medicinal elixirs.

Pharmacologically, alcohol is considered as a drug having **depressant** action on the central nervous system. Medicinal low doses of alcohol are not harmful but consumption of alcohol in high doses causes intoxication and produces various health and social hazards. Nevertheless, consumption of alcohol is common in poor as well as affluent sections of the society. Alcoholism is defined as a chronic disease state caused by persistant and excessive consumption of alcohol interfering with the patient's health and social behavior. In alcohol intoxication, the body loses its control, the individual gradually loses his consciousness and in extreme cases death may occur.

People who get into the habit of drinking usually begin with a small dose, but soon they become habituated and increase the does and frequency of drinking. Regular consumption of large doses of alcohol makes a person alcohol dependent so that he is unable to give up the habit of drinking; this is called alcoholic addiction.

12.7.1. CAUSES OF ALCOHOLIC ADDICTION OR ALCOHOLISM

The habit of drinking alcohol develops due to one or more of the following reasons: [1] social pressure (for giving company to others in drinking in parties, festivals etc.),

- [1] social pressure (for giving company to others in drinking in parties, festivals etc.),
- [2] attempt to escape from such realities of life as disappointment, failure and frustration,
- [3] to get rid of hardship and monotony of everyday life, [4] feeling of independence,
- [5] desire of excitement and [6] liking the taste.

12.7.2. HARMFUL EFFECTS OF ALCOHOLIC ADDICTION OR HAZARDS OF ALCOHOLISM

It is well established that regular intake of alcohol or the habit of drinking is detrimental to the individual's health and family life and is responsible for several community and social problems.

Alcohol is rapidly absorbed from stomach and intestine, and can easily pass through the cell membranes; so it affects more or less all tissues of the body. The major ill effects of consuming alcohol are as follows:—

[1] Neural disorders—Many people drink alcohol for some 'stimulation'. But in reality alcohol is not a 'stimulant' as long believed, rather it is a depressant of the central nervous system having sedative, hypnotic, analgesic and anesthetic effects. It impairs mental alertness, memory, sensory perceptions, power of judgement, coordination of muscles and reflex responses. It produces drowsiness and in heavy doses may even lead to loss of consciousness. Alcoholics often show abnormal behavior such as loss of self restraint and violence, which affect their social life.

[2] Cardiovascular and haematogical disorders—It has been suggested that regular intake of low doses of alcohol may decrease the risk of coronary heart disease. But consumption of excess alcohol is certainly harmful for the blood circulatory system. It causes tachycardia, cardiomyopathy (disorder of heart musele), changes in blood pressure etc. Due to deposition of alcoholic fat on heart, the working of heart is disturbed. Prolonged alcoholism produces anaemia.

[3] Gastro-intestinal and metabolic disorders—Alcohol causes irritation of the mucosal lining of mouth, oesophagus and stomach often associated with vomiting. High doses, specially if taken in empty stomach, leads to gastritis and pancreatitis. It

may even cause cancer of mouth, pharynx, larynx and oesophagus.

Alcohol damages the liver. It decreases neoglucogenesis in liver leading to hypoglycemia. Regular drinking habit causes deposition of excess fat in liver. The condition is called fatty liver, which may ultimately lead to serious liver diseases like alcoholic hepatitis, cirrhosis of liver and even cancer of liver causing death. Effects of alcohol on liver are more severe if the subject is malnourished.

[4] Excretory disorders—Alcohol intake is often associated with diuresis (frequent urination) due to inhibition of the antidiuretic hormone (ADH) secretion. It also interferes with renal excretion of uric acid leading to elevation of blood uric acid level and thus gout.

[5] Reproductive disorders—Alcoholic women often suffer from amenorrhea (absence of menstruation), infertility and spontaneous abortions. In males, alcoholism

may cause testicular atrophy, impotence and infertility.

[6] Infections—Alcoholics usually neglect their health, and particularly those who are poor, suffer from malnutrition. So, their body loses resistance to infections and they are susceptible to diseases like pneumonia.

[7] Effects on family and community (or social hazards)—Addiction to alcohol not only harms the drinker, but also affects the family and community life in the following ways [a] Alcoholic drinks are costly; so, most drinkers because of their selfish attitude, deprive their children and family members of their basic needs. [b] Alcoholism may even ruin a family because of the ill behavior and maladjustment of the drinker with the family members. [c] Alcoholism is often associated with suicide, violence and other social crimes. [d] Intake of alcoholic drink is responsible for occupational hazards like industrial and traffic accidents and low productivity.

12.7.3. HOW TO STOP ALCOHOLIC ADDICTION?

In order to prevent alcoholic addiction, public consciousness has to be grown against it by making the people aware of its serious consequences. If a person who is already addicted to alcohol gives up the habit of drinking, he or she feels uneasy for some days due to the withdrawal symptoms. Such symptoms include tachycardia, anxiety, sweating, tremor, confusion, insomnia, headache, nausea, hallucination, delirium tremens (state of agitation and restlessness), convulsion and collapse. During withdrawal, medical and psychological treatments are needed. Usually, some depressant medicine is used to calm the patient and the medicine is gradually withdrawn later. Psychological treatments require rehabilitation programmes including psychotherapy, group psychotherapy, marital and family therapy, behavioral therapy, occupational programmes etc.

12.8. Drug Addiction

The term 'drug' is derived from the French word 'drogue' meaning 'a dry herb' because most of the drugs are obtained from dried herbs. However, many synthetic substances are also now used as drugs. Drug is defined as any substance or product which is used to modify one or more function(s) of the body for benefit of the recipient. Drugs are normally used as medicines for treatment of diseases.

When a drug is taken repeatedly and in high doses by self-medication without any proper medical reason but for personal satisfaction, it may cause harm to the recipient's health and his community; this is called drug abuse. There are certain drugs called psychotropic (or psychoactive) drugs, which act on the central nervous system to alter the recipient's mental state and behavior. Such drugs are also called 'mood altering drugs.' These are normally used as medicines for treatment of mental illnesses like depression, insomnia etc. Some people wrongly use to take such drugs without any medical advice for their mental satisfaction (i.e. feeling of well being). This of course is harmful for the recipient because it adversely affects his consciousness, power of perception and thinking and also the behaviour. Prolonged abuse of a psychotropic drug leads to a state when the body requires a continuous presence of the substance in it. As a result of this, the person becomes fully dependent on the drug both mentally and physically so that it is difficult for him to live without taking the drug. This condition is referred to as drug dependence. Due to development of drug dependence, the victim is compelled to take the drug regularly, this is called drug addiction and the victim is said to be a drug addict. If a drug addict stops taking the drug in order to get rid of the habit, he often develops serious withdrawal symptoms causing relapse of addiction.

12.8.1. TYPES OF ADDICTIVE DRUGS : THEIR CLINICAL USES AND EFFECTS

The psychotropic drugs producing dependence and addiction are referred to as addictive drugs. However, alcohol and nicotine are also included in this group that have been described earlier. Addictive drugs are classified on the basis of action into four groups [1] depressants (or sedatives, tranquilisers or hypomics i.e. sleep inducing agents), [2] stimulants. [3] opiate narcoties (pain-killers) and [4] hallucinogens. Examples of such drugs, their clinical (or medicinal) uses and effects on the mind of the recipient are shown in Table 12.3.

Table 12.3.: Types of addictive drugs, their examples, clinical uses and mental effects.

effects.			
Type of drug with examples	Clinical uses	Effects	
1. Depressants (Sedatives, tranquili-sers, hypnotics) Examples—Barbiturates, Benzodiazepines (e.g. Valium)	Treatment of insomnta and anxiety or mental tension (i e used as sleep inducing and anti anxiety medicine)	Depress brain activity; produce feeling of calmness, relaxation, drowsiness, and deep sleep (in high doses).	
2. Stimulants Examples-Amphetamines, Cocaine, Caffeine (very mild)	Treatment of attention deficit, narcolepsy (recurrent uncontro- liable desire for sleep) and obesity.	Stimulate nervous system; make a person more wakeful; increase alertness and activity; produces excitement.	

Type of drug with examples	Clinical uses	Effects
3. Opiate narcotics Examples-Opium, Morphine, Codein, Heroin, Pethidine, Methadone.	Used as analgesics (or pain killers).	Suppress brain functions; provides relief from intense pain (both physical and mental); produce temporary euphoria (sense of well-being).
4. Hallucinogens Examples-Canna-binoids (Bhang, Ganja, Hashis or Charas and Marijuana), LSD, Mesacaline, Psilocybin.		Alter perceptions, feelings and thoughts; produce hallucinations (false sensory impressions usually visual or auditory in absence of actual stimulation).

12.8.2, SOME COMMON ADDICTIVE DRUGS

The drugs which are commonly used for addiction, their sources, the form in which they are used and their ill effects are described below briefly.

- [1] Barbiturates and benzodiazepines: These are synthetic drugs used in 'sleeping pills'. Use of these drugs for the purpose of addiction is dangerous because of two reasons—(i) it leads to craving i.e. both physical and psychic dependence and (ii) if taken in high dosess it can be lethal. These are frequently used for suicides.
- [2] Amphetamines: These are also synthetic drugs often used in pep pills (energy giving pills). Night workers and truck drivers sometimes use such pills to keep them awake. These drugs cause mood elevation, elation, a feeling of well being and a tremendous boost to self confidence and energy; so they are also called 'superman drugs.' However, these drugs may impair judgement, vision and may even produce hallucinations. Higher doses of these drugs may produce sleeplessness and nervousness followed by a severe let down.
- [3] Cocaine: It is an alkaloid derived from the leaves of coca plant. (Erythroxylon coca). In medical practice it is used as a potent local anesthetic. It is a stimulant drug. When taken internally, it produces a sense of excitement and pleasure but later the victim is seized by a feeling of fear and may become violent. On continuous use, it causes insomnia, loss of appetite and hallucinations and may ultimately lead to mental disorders and insanity.
- [4] Opium and its derivatives: Opium is a dark-brown resinous material obtained from the unripe capsules of poppy plant (Papaver somniferum). Morphine and codeine are alkaloids derived from opium. Heroin is a synthetic compound prepared from morphine. Pethidine and methadone are two synthetic drugs that are chemically not related to morphine (opium) but their actions are similar to morphine.

Opium is either taken orally or smoked by the addicts. Morphine and pethidine are used clinically as analgesies. Codeine is used in cough syrups. Morphine, heroin, pethidine, methadone and codeine are often taken by subcutaneous injections by the addicts. Some addicts also use codeine containing cough syrups in excess doses. These drugs reduce respiratory and cardiovascular activity, and in high doses may even cause death.

[5] Cannabinoids: These are products of the hemp plants-Cannabis sativa, Cannabis indica and Cannabis americana. Cannabinoids are obtained from dried leaves and flowers of the hemp plant and used in different forms called bhang, ganja, charas

(or hashish) and **marijuana**. These have no medical use and are taken for addictive purpose only.

Bhang is taken orally with milk products and the others are mixed with tobacco and smoked. The effects of using such drugs are unpredictable. The user often remains in a dream like state; some become violent and bring danger for themselves and others.

[6] LSD: It is the abbreviation of lysergic acid diethylamide. It is derived from the ergot alkaloids (products of a fungus) and is usually taken orally. It has no clinical use. LSD affects the mind and alters perception causing visual or auditory hallucinations. Its prolonged use may lead to mental breakdown and depression.

Addiction to any drug is harmful. Some addicts often use a drug in combination with alcohol or other drugs; this is much more dangerous because one drug may potentiate the effects of the other and in such case treatment is more difficult.

12.8.3. CAUSES OF DRUG ADDICTION:

Drug addiction is not found among well adjusted, satisfied and happy people. It is more common among those who are under stress and feel insecure. These people are not satisfied with themselves and try to assume imaginary personalities. The major reasons of drug addiction are as follows:

[1] Curiosity, excitement and adventure—Reference to drugs in literature and mass media makes a person curious to have a personal experience of the drugs. Many young people start taking drugs for the sake of adventure and excitement specially because intake of drugs is illegal.

[2] Peer group pressure—Drug addicts often express about the good feelings

created by drugs and they inspire their friends to begin with drugs.

[3] Relief from mental stresses—Many people start taking drugs to overcome mental stresses and depressions caused by disappointments, frustrations, failures, unemployment, fatigue, loneliness, monotony, insecurity etc.

[4] Relief from pain—People suffering from persistent pain use drugs to get relief

from it.

[5] Desire to increase working power—Some people use stimulant drugs to increase their ability to do more mental and physical work. For example-many students take such drugs before examinations so that they can study till late night.

[6] Occupational factors—People engaged in certain occupations like sales and tourism, who often live away from their homes, are more prone to drug addiction. Those engaged in drug-trading are mostly drug addicts because drugs are easily available to them

[7] Family and community factors—Drug addiction is common among children of the families where parental love, care and control are lacking. When the parents or elder members of a family are drug users, the children are inspired to take drugs. Drug addiction is more common in areas with high rate of crimes and easy availatility of drugs.

12.8.4. SYMPTOMS OF DRUG ADDICTION

Drug addicts usually show the following characteristic features by which they can be detected: -[1] Loss of interest in daily routine as well as sports and recreations.

[2] Loss of appetite and body weight. [3] Reddening and puffiness of eyes, unclear vision. [4] Slurring of speech. [5] Drowsiness or sleeplessness, lethargy and passivity.

[6] Acute anxiety, depression, profuse sweating, nausea, vomiting and body pain. [7] Changing mood and temper. [8] Impaired memory and concentration, depersonalisation

and emotional detachment. [9] Unsteady gait, clumpsy movements and tremors. [10] Numerous, fresh injection marks on body and blood stains on cloths, and presence of syringes, needles and strage packets at home.

12.8.5. HAZARDS OF DRUG ADDICTION

From the above discussion it is quite clear that addiction to drugs affects both the mental and physical health of the victim. The body fails to work without drugs. Prolonged use of drugs causes permanent damage to various organs. The drug users, who share syringes and needles with others for taking the drug by injection, often become victims of blood borne infective diseases like hepatitis and AIDS. They can even die from such infections or overdose of the drug or suicide. Since they get the drugs from illegal sources, they often become associated with smuggling and other illegal activities that may lead to imprisonment. The drug users not only suffer themselves but also bring miseries to their family and community.

12.8.6. CONTROL OF DRUG ADDICTION

In order to control (or get rid of) the problem of drug addiction, following preventive and remedial measures are necessary.

- [1] Legal measures—Proper legislation should be made to control the manufacture, distribution, prescription, sale and consumption of addictive drugs.
- [2] Educational measures—Educational programmes for school children and public information campaigns are to be arranged to develop awareness against drug addiction. Problems and stresses are increasing day by day in modern life, which is responsible for drug addiction. So, people should learn to face the problems and stresses and to accept disappointments or failures as normal parts of life.
- [3] Medical measures—Drug addicts are to be identified and hospitalised for detoxification treatments. Arrangements should be made for post-detoxification counselling and follow-up (based on clinic and home visits) to prevent relapse of addiction.
- [4] Community measures and rehabilitation—Simulta-neously with medical treatment, changes in social environment (home, school, college and social circles) are also important. The patient must be detached from his bad associates and provided with facilities for rehabilitation. For this, the family members and community should show sympathetic and loving attitude to a former drug user and avoid panic, moral condemnation and discrimination. Facilities for vocational training and work opportunities are also very important for rehabilitation, and help to prevent relapse.

REVISION

Nicotine—An alkaloid present in tobacco, responsible for tobacco addiction and its hazards.

Alcoholism—A diseased state due to addiction to alcoholic beverages.

Drug—A substance modifying any body-function, normally used for treatment of disease.

Drug abuse—Intake of a drug by self-medication in such doses that is harmful and not medically recommended.

Psychotropic (or Psychoactive) drugs—Drugs acting on and modifying the functions of central nervous system.

Drug addiction—Compulsion to take a psychotropic drug regularly, developed due to prolonged abuse of the drug.

12.9. Global Immunization: Pulse Polio

12.9.1. BASIC CONCEPT OF IMMUNITY AND IMMUNIZATION

Immunity: The term immunity has originated from the Latin word 'immunis' meaning 'exempt' or 'freedom' and refers to resistance of the body to deleterious effects of foreign agents like bacteria, viruses or other pathogenic micro-organisms. Such infective agents contain or produce some disease producing materials called antigens or toxins. Immunity is attributed to presence of some proteins in blood, called immunoglobulins or antibodies. An antibody is produced in the body in response to entry of an antigen and reacts with the same antigen to mactivate it. Thus, antigens are antibody generators and antibodies are antigen destroyers or anti-antigens.

Immunity can be acquired **passively** by obtaining a 'pre-formed' or 'ready-made' antibody (which is produced in another individual's body), or **actively** by producing antibody in an individual's own body in response to entry of an antigen. The passive immunity takes less time to develop and its effects are short-lasting, while the active immunity takes more time to develop and its effects are long-lasting.

A newborn baby is provided with some natural passive immunity which he acquires from his mother. This is due to transmission of maternal antibodies to the baby across the placenta (before birth) as well as through mother's milk (after birth). The maternal antibodies transmitted to the baby lasts for about 6-12 months and cannot protect the child from various infective agents to which he is exposed thereafter. This is why, in earlier days, mortality due to infections, specially the child mortality was very high. However, it has long been noticed that survivors of certain diseases like small pox, measles etc. are not attacked by the same disease again. This is because when a person is attacked by a disease (i.e. an antigen enters into the body), he acquires active immunity due to production of antibody in his body for fighting out the disease. When an antigen enters into the body for the first time, the antibody production or the primary immune response is relatively slow and short-lasting. However, the immune system of body retains a memory of the antigen so that when the same antigen invades again, it evokes a heightened secondary immune response (i.e. antibody production is much more rapid and long lasting). Based on this knowledge, vaccines have been developed for immunization against many diseases and as a result, child mortality has been checked considerably.

Immunization: Immunization is an artificial means of imparting immunity against infections and toxins. It may be of two types—passive and active. Passive immunization is done by injecting an antibody, usually in the form of antiserum (serum containing an antibody e.g. ATS or anti-tetanus serum. The antiserum is nothing but a sample of serum obtained from the blood of an animal (usually horse) in which an antibody has been developed by injecting small doses of a disease producing germ at intervals. The passive immunization is of little value in prevention and mass control of a disease. But because its effects are immediate, it is useful as a curative measure in cases of emergency like treatment of tetanus, rabies, snake bite etc. where there is insufficient time for the victim to develop a strong active immunity.

Active immunization is done by introducing antigens in form of vaccines so that antibodies are developed in the recipient's body to protect him from attack of diseases in future. The active immunization is a very useful and powerful preventive measure for mass control of many diseases. A vaccine is an antigenic preparation containing killed or live but attenuated (weakened) germs or a toxoid (a toxin treated in such way to destroy its deleterious properties without destroying its ability to stimulate antibody production). A vaccine when introduced into the body (vaccination), does not produce the disease but stimulates antibody formation.

Edward Jenner, an English physician, first discovered a vaccine (the small pox vaccine) in 1798. Since then many vaccines have been developed against diseases like cholera, typhoid, tuberculosis, whooping cough, rabies, measles, mumps, plague, diphtheria, polio, tetanus, hepatitis-B etc. In spite of extensive researches, unfortunately vaccines against certain diseases like malaria, diarrhoeal diseases, AIDS and cancer are not yet available. Vaccines are usually introduced by scarification (cutting the skin) or by inoculation (injection). However, a polio vaccine is now available which can be given by mouth (oral polio vaccine).

12.9.2. IMMUNIZATION PROGRAMME: GLOBAL IMMUNIZATION

Certain infectious diseases like polio, tetanus, diphtheria, measles, pox etc. can be prevented and controlled by active immunization (vaccination). So, vaccination against these diseases is given as a routine during infancy and early childhood with periodic booster doses to maintain adequate levels of immunity (antibodies in blood). However, there are immunizations against certain other diseases e.g. cholera, typhoid, plague, influenza. yellow fever etc., which are offered to high-risk groups or restricted to definite geographic areas where such a disease is endemic or a public health problem. Immunization is a mass means of protecting greatest number of people. For this, immunization has to be planned according to the needs of the situation; this is called immunization programme. Every country has its own immunization schedule prepared according to the suggestions of world health organization (WHO) and national health agencies. The main purpose of the immunization programmes is to vaccinate children at the right age i.e. when they have lost the antibodies transmitted by the mother and before they are exposed to possible infections. In order to minimise the number of visits to a clinic for vaccination, different vaccines are administered simultaneously. The utility of immunization (vaccination) programmes is evidenced by eradication of small-pox, a dreadful infectious disease, from the whole world since 1977.

In 1974, the WHO launched a world-wide (i.e. universal or global) immunization programme known as **Expaned Programme on Immunization** (or EPI) to protect all children of the world against six vaccine-preventable diseases namely—diphtheria, whooping cough (pertussis), tetanus, polio, measles and tuberculosis (TB) by the year 2000. The programme is now called **universal child immunization programme**. This programme was launched in India in 1985.

The schedule of global immunization programme (or EPI) recommended by WHO is given in table—12.4.

Table-12.4: The schedule of EPI:

Age	Vaccine
Birth.	BCG (Bacillus calmette guerin vaccine for
	tuberculosis) and OPV (oral polio vaccine)
6 weeks	DPT (Diphtheria-Pertussis-Tetanus vaccine) and
	OPV
10 weeks	DPT and OPV
14 weeks	DPT and OPV
9 months	Measles Vaccine

The WHO has recommended BCG and polio vaccine to be given at birth or at first contact specially in countries where tuberculosis and polio have not been controlled. In all countries, routine immunization with DPT and polio vaccine can be safely and effectively started at 6 weeks of age. The immunization schedule given in the above table is considered as the best. However, it may be altered to suit the needs of the individuals. The common belief that if the second or third dose in an immunization is delayed, the immunization schedule must be started all over again, is baseless. In fact, interruption of the schedule due to delay between the doses does not interefere with the final immunity achieved. Immunization is often postponed if a child is ill or malnourished; this also has no basis. Malnutrition and minor illnesses like low fever or mild respiratory infections or diarrhoea should not be considered as contraindications to immunization. In fact, such children should definitely be immunized because they are most likely to die if they acquire a vaccine preventable disease.

Recently, the WHO has suggested to extend the immunization programme beyond infancy by including children, adolescents and pregnant women in the target group for immunization. New vaccines against diseases like hepatitis-B, influenza, Japanese encephalitis, rubella (German measles) etc. are being added to the vaccination schedule for those who are at risk.

12.9.3. PULSE POLIO

Poliomyelitis (or polio in short) is a crippling disease caused by a RNA-virus called polio-virus. The infection occurs mainly in infants and children at an age between 6 months to 3 years. In pre-vaccination era, polio was found in all countries of the world. After the discovery of polio vaccine, the disease has been eliminated from developed countries. Although the routine immunizations with oral polio vaccine (OPV) as per the EPI schedule mentioned earlier have markedly decreased the incidence of polio in our country, the disease has not been totally eradicated. So, the government of India has launched a special immunization programme against polio, known as 'pulse polio', with an aim to facilitate global eradication of polio, as suggested by the WHO. The programme was funded by Rotary International.

The 'pulse polio' is a nation-wide immunization programme in which two doses of OPV are given 4 to 6 weeks apart, each dose being given to all children at risk (i.e. below 3 years of age) in the country, on the same day (referred to as national immunization day or NID). The pulse polio immunization (PPI) requires mass campaigns through news papers, radio, television etc. to fulfil its target. Government of India conducted the first round of PPI consisting of two NID 6 weeks apart on 9th December

1995 and 20th January 1996. The first PPI targeted all children below 3 years of age. Later, as recommended by WHO, the age group of the targeted children has been raised from under 3 to under 5 years. The PPIs are conducted during low transmission season of polio, *i.e.* between November to February, when doses of OPV are given to all children 0-5 years of age irrespective of their previous immunizations with OPV. The doses of OPV given during PPIs are extra doses which supplement and do not replace the doses given during routine immunizations (EPI). Thus, all children below 5 years of age including 0-1 year old infants should receive all their scheduled (EPI) doses as well as PPI doses of OPV.

REVISION

Immunity—Resistance of the body against infective and toxic agents.

Immunization—An artificial way of imparting immunity.

Passive immunization—Injection of an antibody to fight out the deleterious effects of an infection or toxin.

Active immunization—Administration of an antigen (vaccine) to develop immunity in the recipient's body.

Vaccine—An antigenic preparation used for active immunization

Vaccination—Introduction of a vaccine into the body.

Inoculation—Injection of an antigen or antibody.

Pulse polio—A special nation-wide immunization programme against polio conducted in the whole country on the same day.

12.10. Matters to Recollect

- Population characteristics are-density, natality, mortality, age distribution, biotic potential, dispersal and growth form.
- The J-shaped population growth form is density independent.
- The S-shaped population growth form is density dependent.
- Population dynamics refers to study of population growth.
- Population growth depends on the population characteristics.
- Demography is based on census.
- Overpopulation is a great problem of undeveloped and developing countries.
- Mental illness leads to failure of adjustment with the society.
- Mental illnesses are mainly of two types psychosis and neurosis.
- Addiction to tobacco, alcohol and drugs is harmful for the addict as well as his community.
- Excessive tobacco smoking may lead to lung cancer.
- Excessive tobacco chewing may lead to oral cancer.
- Alcoholism may cause cirrhosis and cancer of liver.
- Drug addicton is a criminal offence.
- Immunization (vaccination) in infancy and childhood is necessary for protection against infections.

- ATS anti-tetanus serum is used as a passive immunizing agent for treatment of tetanus.
- Tetanus toxoid is a sterile preparation of tetanus producing bacteria (Clostridium tetant) used as an active immunizing agent or vaccine for prevention of tetanus
- DPT vaccine is a combined vaccine for diphthena, pertussis (whooping cough) and tetanus.
- BCG (Bacillus calmette guerm) vaccine is the vaccine for tuberculosis.
- **OPV** is oral polio vaccine, i.e. a polio vaccine which is given orally.

12.11. Summary

The term population refers to a group of individuals of the same species living within a given space. The total number of individuals in a population is termed population size and the population size per unit area or volume of the habitat is called population density. A population has some group properties e.g. natality, mortality, age distribution, biotic potential, dispersal and growth form. Population growth refers to increase in population size over a period of time. The pattern of population growth in relation to time i.e. the population growth form is represented mitial lag phase and an exponential phase) and S-shaped (or sigmoid, having an initial lag phese, a middle exponential phase and a final stationary phase). Population growth depends on various factors e.g. natality, mortality, dispersal, age and sex composition, biotic potential and environmental resistance. The maximum size of population that can be supported by the environment is called maximum carrying capacity. The study of human population is called demography which is based on census reports. The pace of population growth is denoted by annual averge growth rate and doubling time. Overpopulation refers to a high density of human population in a geographic area. It is a burning problem particularly in developing countries. It is caused by low death rate, high birth rate, increased availbility of resources and migration. Harmful effects of overpopulation includes unemployment, poverty, shortage of food, shelter and clothing, low level of education and health, environmental pollution and social imbalance.

Mental health refers to ability of an individual to adjust with the society and various situations of life. Mental illnesses impair normal life (i.e. behaviours, attitudes, feelings etc.) of the victim. Major mental illnesses are called psychoses which include scizophrenia, mood disorders and paranoia. Minor mental illnesses include neurosis and disorder of personality and character. Mental illnesses are caused by changes in brain, childhood experience, family atmosphere and hereditary and socio-economic factors. Such illnesses are treated by electroshock therapy, psychotropic drug therapy, psychotherapy and social therapy.

Addictions to tobacco, alcohol and psychotropic drugs are major community health problems. They not only harm the addicts but also their families and community. Such addictions are caused by curiosity, peer group pressure, mental stress and occupational and social factors. Use of such materials for addiction should be discouraged for the benefit of the society. For this, proper legal, educational, medical and social measures should be taken.

Immunization by vaccination is very important for protecting the mankind from various infections. For this every infant should be vaccinated as per the global immunization schedule recommended by WHO. Pulse polio is a country-wide immunization programme against polio which aims to give oral polio vaccine to all children of the country upto 5 years of age, on the same day.

12.12. Naming / Discovery / Discoverer

- [1] T.R. Malthus (1778) showed that human population grows in geometric progression but the resources grow in arithmetic progression.
 - [2] Edward Jenner (1798) discovered smallpox vaccine.
 - [3] Louis Pasteur (1885) discovered rabies vaccine.
 - [4] Salk (1954) discovered the injectable polio vaccine.
 - [5] Sabin (1957) discovered the oral polio vaccine.

12.13. Answer to Special Questions

[1] What is a vaccine?

[JEE 1997,'99]

Ans. A vaccine is an antigenic preparation containing suspension of killed or live but attenuated (weakened) germs (bacteria, viruses etc.) or a toxoid, administered for developing specific antibody in the recipient's blood to protect the recipient from the attack of a disease.

[2] What is a booster dose of vaccination?

JEE 1999]

Ans. A booster dose of vaccination is a subsequent dose of vaccine given after the primary dose(s) to develop the effective and high level of antibody in blood for long lasting immunity.

[3] What is the difference between vacination and inoculation? or Explain the terms 'vaccination' and 'inoculation'.

Ans. Vaccination means introduction of a vaccine (antigen) into the body by scarification (cutting the skin) or injection or through oral route (in case of polio). Inoculation means introduction of a vaccine (antigen) or antiserum (antibody) into the body by injection. Thus, vaccination by injection is inoculation.

[4] Why smoking is referred to as a bad habit?

Ans. Smoking is a bad habit because it causes various harms to the smoker himself as well as his fellow men, who may not like it but are forced to inhale the smoke as passive smokers. It has adverse effects on respiratory, circulatory, gastrointestinal, endocrine and reproductive systems leading to their disorders. Excessive smoking may also lead to cancer in lungs, throat or other organs. Teeth and fingers of the smoker become stained and look ugly. Smokers often throw the burning residues of cigarettes and bidis here and there that may lead to spread of fire.

[5] Suggest some measures to restrict the use of tobacco.

Ans. (i) To make the people aware about the hazards of using tobacco by conducting mass campaigns.

(ii) Legislations are to be made prohibiting smoking and spitting of tobacco in public places like buses, trains, offices etc.

- (iii) Printing of health warnings on packets of tobacco products to be made mandatory.
- (iv) Heavy taxes to be implemented on tobacco products.
- (v) Cultivation and trading of tobacco to be discouraged.
- [6] Among tobacco smoking and consumption of alcohol, which one do you think to be more harmful for community health? Give reason.

Ans. Tobacco smoking is more harmful for community health in comparison to alcohol consumption. Reasons: (i) Smoking causes harm to others who do not smoke, while alcohol causes harm to the user only.

(ii) Smoking has no good effect while consumption of alcohol in measured low doses may have some medicinal value.

EXERCISE

• A. I	Essay type /Long answer type:	
[1]	Draw population growth curves and explain them.	(Ans. 12.2.1)
[2]	Describe the factors affecting population growth	(Ans. 12.2.2)
[3]	What is population explosion? Describe the causes of population explosi-	on. (Ans. 12.4.1)
[4]	Discuss the effects of overpopulation.	(Ans. 12.4.2)
[5]	What is mental illness? Describe briefly the types of mental illnesses.	(Ans. 12.5.1.B)
[6]	Discuss the causes of mental illness?	n. 12.5.1.C)
[7]	What are the different types of treatments for mental illness?	(Ans. 12.5.1.D)
[8]	Describe the harmful effects of addiction to tobacco?	(Ans. 12.6.2)
[9]	Describe briefly the harmful effects of alcoholism?	(Ans. 12.7.2)
[10]	What is drug addiction? Give an account of different types of addictive of	drugs mentioning their effects
	and clinical uses,	(Alla: 12:0:1)
1111	Describe the reasons of drug addiction.	(Ans. 12.8.3)
[12]	How drug addiction can be controlled?	(Ans. 12.8.6)
[13]	Write what you know about global immunization.	(Ans. 12.9.2)
[14]	Write what you know about the pulse polio immunization.	(Ans. 12.9.3)
	Short answer type:	
[1]	What do you mean by population ?	(Ans. 12.1)
[2]	What are population size and population density?	(Ans. 12.1.1)
[3]	Mention the characteristics of a population.	(Ans. 12.1.2.)
[4]	What do you mean by population growth?	(Ans. 12.2)
[5]	What do you mean by population growth forms and population growth or	urve? Mention their types?
[5]	What do you mean by population grant in the	(Alla: 14:4:1)
[6]	What is Malthus' theory of human population growth?	(Ans. 12.4.2)
171	What is annual average growth rate?	(Ans. 12.3.; 12.3.1.; 12.3.2)
[8]	ALM C. C. A. A. Marin Lance 2	(Ans. 12.3.; 12.3.1; 12.3.2)
[9]	What are biotic potential and maximum carrying capacity and how t	hey are related to population
[2]	growth?	(12113: 14:4:4)
[10]	Why the death rate of human population has decreased?	(Ans. 12.4.1)
[11]	via	(Ans. 12.4.1)
[11]	What do you mean by emigration and immigration? How do they influe	nce a human population?
[12]		(VISIO ITITIONAL AND
[13]	Explain the interrelationship between the level of education and population	on growth of a country.
[13]	Explain the interretationary	(MIIS-12-4-1, 12-1-12)
[14]	How overpopulation is related to pollution?	(Ans. 12.4.2)
[15]	What are the characteristics of a mentally healthy person?	(Ans. 12.5)
[16]	What are the characteristic features of a man who is mentally ill?	(Ans. 12.5.1A)
[17]	What is psychosis?	(Ans. 12.5.1B)
[18]	What is schizophrenia?	(Ans. 12.5.1B)
[19]	What is neurosis?	(Ans. 12.5.1B)
1201	What is electroshock therapy?	(Ans. 12.5.1D)
[20]	Mildr 19 Cicerositons mores.	

[21]	What is tohacco? How is it used by persons who are addicted to	it? (Ans. 12.6.)
[22]	What is tobacco addiction?	(Ans. 12.6.1)
[23]	Why tobacco smoking is more harmful than tobacco chewing?	(Ans. 12.6.2)
[24]	What are the toxic materials present in tobacco smoke?	(Ans. 12.6)
[25]	How is the use of tobacco related to cancer?	(Ans. 12.6.2)
[26]	What are 'alcoholic addiction' and 'alcoholism'?	(Ans. 12.7)
[27]	Mention the causes of alcohoric addiction.	(Ans. 12.7.1)
[28]	What are the social hazards of alcoholic addiction?	(Ans. 12.7.2)
[29]	Mention the withdrawal symptoms of alcohol.	(Ans. 12.7.3)
[30]	How alcoholic addiction can be stopped?	(Ans. 12.7.3)
[31]	What do you mean by 'alcohols' and 'alcoholic beverages'?	(Ans. 12.7)
[32]	Define 'drug' and 'drug abuse'.	(Ans. 12.8)
[33]		sychoactive) drugs? (Ans. 12.8)
[34]		is. (Ans. 12.8.1)
[35]	Mention the symptoms of drug addiction.	(Ans. 12.8.4)
[36]	What are the hazards of drug addiction?	(Ans. 12.8.5)
[37]	What do you mean by 'active immunization' and 'passive immur	ization'? (Ans. 12.9.1)
[38]	What is a vaccine?	[JEE 1997, '99] (Ans. 12.13, Q-1)
[39]	What is the purpose of vaccination?	(Ans. 12.9.1)
[40]	What is booster dose of vaccination?	[JEE 1999](Ans. 12.13. Q-2)
[41]	What is the difference between vaccination and inoculation?	(Ans. 12.13, Q-3)
[42]	Give the full name of the following—	
	(a) COPD, (b) LSD, (c) ATS, (d) BCG vaccine, (e) DPT vaccine,	
		(Ans. 12.6.1; 12.8.2; 12.9.1; 12.9.2)
• C.	Write brief notes on:	
	world (Ans. 12.3.1) [4] Trends of human population in India.(Al. 12.4.) [6] Psychosis.(Ans. 12.5.1.B) [7] Tobaco addiction.(Ans. 12.7) [9] Drug addiction (Ans. 12.8)[10]Depressant drugs (Ans. 12.8.1; 12.8.2). [12] Cannabinoids (Ans. 12.8.2) [13] Halli Vaccination. (Ans. 12.9.) [15] Pulse polio.(Ans. 12.9.3)	12.6) [8] Alcoholic addiction.(Ans. 12.8.1: 12.8.2) [11] Omate parcetics
• D.	Complete the following sentences writh suitable words:	
[1]	The term 'population' has originated from the Latin word——.	
[2]	The statistical study of human population is called	
[3]	is the most populous country of the world.	
[4]	With the advancement of medical science,—rate has decreas	ad.
[5]	Insomnia means lack of——.	cų.
[6]	The chief toxic material of tobacco is	
[7]	The alcohol present in alcoholic drinks is-	
[8]	The organ most seriously affected by alcohol is-	
[9]	The term 'drug' is derived from the French word-	
[10]	Antigens are generators.	
• E.	Choose the correct answers from those given in parentheses to co	implete the following statements :
[1]	Natality refers to (death rate/birth rate/growth rate)	unbiere the following statements:
[2]	The Jshaped population growth form is density——(dependen	t / independent)
[3]	The maximum carrying capacity is inversely proportional to-	(hiotic potential/envisormental
	resistance).	- (orone potential/environmental
[4]	The population density of India is-than that in USA (greater	r/less)
[5]	The annual average growth rate of world population has ——in	recent years (incressed/dangers)
[6]	One of the causes of overpopulation is ———————————————————————————————————	ly marriages/emigrations)
[7]	Mental filness——hereditary. (may be/is not).	
[8]	Tobacco smoking maximally affects the system, (circulator	V/respiratory/nervous)
[9]	Heroin is derived from——(bhang / ganja / charas / opium).	,, atory mortous)
[10]	is used in sleeping pills. (Barbiturate/LSD/ Cocaine)	
	· · · · · · · · · · · · · · · · · · ·	

• F. State whether the following statements are true or false:

[1] Overpopulation leads to unemployment.

[2] The maximum rate of reproduction of a species under optimal condition is called maximum carrying capacity.

- [3] Tobacco smoking increases the risk of heart diseases.
- [4] Elation refers to emotional excitement.
- [5] Schizophrenics remain in a dream world.
- [6] Benzodiazepines are used in pep pills.
- [7] Hashis is a product of hemp plant.
- [8] LSD is a stimulant drug.
- [9] Vaccine was first discovered by Louis Pasteur.
- [10] DPT vaccine is used for immunization against diphtheria, polio and tuberculosis

Answers to Q. Nos D, Eand F.

- D. [1] Populus. [2] Demography. [3] China. [4] Death. [5] Sleep. [6] Nicotine. [7] Ethanol. [8] Liver. [9] Drogue. [10] Antibody.
- E. [1] Birth rate [2] Independent. [3] Environmental resistance. [4] Greater. [5] Decreased. [6] Early marriages. [7] May be. [8] Respiratory. [9] Opium. [10] Barbiturate.
- F. [1] True. [2] False. [3] True. [4] True [5] True. [6] False [7] True [8] False [9] False [10] False.

Environmental Biology

Topics Discussed: Ecology Introduction, Types, Community, Types of community, Plant succession and climax community, Ecosystem Definition, Components, Types, Food chain & food web, Ecological pyramids, Energy flow, Lindemanns data, Biogeochemical cycle, Types, Biosphere, Biosphere Reserve, Sundarban biosphere, Environmental pollution: Pollutants, Air, Water and Soil, Pollution, Noise pollution and radioactive hazards, Bio-magnification, Bio accumulation, Effect of lead, cadmium, mercury, Ozone hole, Acid rain, BOD, COD, Thermal pollution, Toxicology of industrial waste, Wetland as nature's kidney, Environment protection laws in India, Green bench, Pollution control board, Earth summit.

13.1. Ecology: Introduction

The mode of life of an organism depends largely on the environment, where it lives. The subject was considered as a separate branch of biological science by the German zoologist E. Haeckel (1866) and it concerns with the relationship of plant and animals with the environment. The word Ecology comes from the Greek word Oikos (house) and logos (study). It is concerned with the interaction of the physical environment (portion of hydrosphere, lithosphere and atmosphere) commonly referred to as biosphere and the living components which include the producers, consumers and the decomposers. The interaction is mainly observed in immediate environment of the organisms referred to as microhabitat.

13.1.1. DEFINITION:

The branch of biological science dealing with the inter-relationship between the living organisms with and to their environment is known as ecology.

13.1.2. TYPES OF ECOLOGY:

Ecology can be mainly of two types viz:

- (a) Autecology: It is concerned with the study of individual species in relation to the environment. e.g.: study of single Pinus plant in relation to the environment.
- (b) **Synecology**: The study of a group of organisms taken together as a unit in relation to the environment. *e.g.*: study of a *Pinus* forest in relation to the environment. It has two major branches *viz*: (i) **Community ecology** and (ii) **Ecosystem**.

13.2. Ecological Community

- [1] **Definition:** A community or bio-coenose is an assemblage of organisms forming a distinct ecological unit. When different organisms like plants, animals, fungi and bacteria remain in close association, they constitute a **biotic community**. The size of a community may be very big like the tropical rain forest or it may be microscopic like the phylosphere organisms of a large banyan leaf.
- [2] Types of Community: Biotic communities can be classified on the basis of their size and the nature of the habitat and they are as follows:
- [a] Major Community: These communities represent complete units of ecology or ecosystems and their habitats are distinctive in nature e.g. Tropical rain forest.

- [b] Minor Communities: They do not always represent distinct groups with distinctive habitats and they are often called societies and normally remain in association to constitute a major community *e.g.*: Rhizosphere organisms of big trees.
- [3] Members of Biotic Community: The classification of plant life forms in a biotic community was given by Christen Raunkiaer in 1934. This classification mainly includes five major forms of higher plants.
- [a] **Phanerophytes:** These are trees, shrubs or climbers present in tropical regions but are gradually reduced in the temperate and polar regions.
- [b] Chamaephytes: These plants are small having a height of maxium 25 cm remaining in the temperate regions.
- [c] Hemicryptophytes: These are biennial or perennial herbs of cold climatic regions having perennating buds protected under the soil surface.
- [d] Cryptophytes or Geophytes: They mostly include plants having bulbs and rhizomes, which survive underground during adverse climatic conditions.
- [e] **Threophytes:** They include annual plants reproducing during favourable condition by the production of flowers and seeds.

The plants members of a biotic community can also be classified on the basis of life forms, plant size, function, leaf shape, leaf texture and canopy cover (**Dansereau**, 1957).

13.2.1. PLANT SUCCESSION:

The process by which one community replaces another community in a particular habitat is known as plant succession. This ultimately results in the development of a stable community known as climax community.

- [a] **Primary Succession:** This succession is also called **autotrophic succession** and takes place in the barren area or sterile area like barren rock or sand dunes. They include the following stages.
- (i) Nudation: The soil surface or the rock is exposed due to the physical forces of the nature.
- (ii) Migration: The plant parts or propagules are transferred to that barren area.
- (iii) Colonization: The primary colony develops due to propagation of a single plant.
- (v) Aggregation: This is the last stage of primary succession, when the colony becomes stable due to increase in population of the same species.
- [b] Secondary Succession: The succession is also called heterotrophic succession because in this process a stable community is replaced by another community resulting in the development of seres and ultimately it ends with the development of climax community. This type of succession is involved in the transformation of aquatic community (hydrosere) to terrestrial community. The stages can be described in the following way:

Pond Ecosystem

Phytoplanktons

Rooted aquatic plants

L

Free floating and rooted plants

1

Reeds and sedges

 \downarrow

Mesic communities

1

Open scrub land

 \downarrow

Deciduous forest

Thus each of the seres mentioned above shows a gradual evolution from pond ecosystem to terrestrial ecosystem and the deciduous forest becomes the climax community.

13.3. Ecosystem

The ecosystem is the basic functional unit of ecology, where the living and non-living members exhibit close interaction. The green plants prepare the food, the animals procure their food form them and the decomposers help in recycling of those materials back to the nature. The ecosystems normally vary from habitat to habitat.

- [1] History: (i) Haeckel (1866) first tried to define ecosystem.
- (ii) Tanslay (1935) first coined the word ecosystem for better understanding of ecology.
- (iii) Odum (1959), Werner (1966) and Kendeigh (1967) explained the various aspects of interaction and inter-relationship between the living components of ecosystem.
- [2] **Definition**: Ecosystem is the functional unit of ecology, which deals with the inter-relationships between the living and non-living components of the environments.
- [3] Components of Ecosystem: The components of an ecosystem can be divided into 2 types: [I] Abiotic component [II] Biotic component.
- [I] Abiotic or Non-living Components: The abiotic components are mainly of 2 types, the physical or climatic factors and the chemical factors including inorganic and organic substances:
- [a] **Physical factors:** They include sunlight, temperature, humidity, atmospheric pressure prevailing in all the areas of the biosphere *viz.* atmosphere, lithosphere, hydrosphere. They are as follows:

(i) Light: The light primarily comes from solar source, which acts as the only major source of energy in the ecosystem. Though other non-conventional energies in the form of wind, geothermal, tidal are being harnessed in recent years.

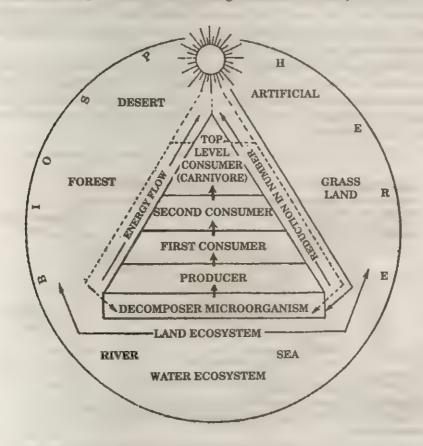


Fig. 13.1: Schematic representation of global ecosystem

- (ii) Temperature: This is another important factor for sustaining life, though the tolerance of temperature varies from organism to organism. But on an average the maximum temperature at which life is possible, is 45°C.
- (iii) **Humidity**: The relative humidity helps in the growth of micro-organisms and plants, it is also helping the growth and respiration of some animals.
- (iv) Atmospheric pressure: The superincumbent pressure of air is 14.7 lbs. per square inch at sea level, it decreases with altitude and along with it, the concentration of oxygen is also reduced and this makes breathing difficult.
- (b) Chemical factors: They include the inorganic elements like carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulphur, calcium, magnesium etc., which are primarily present in the soil and constitute the bio-geo chemical cycles like carbon cycle, oxygen cycle, nitrogen cycle. The organic compounds are mainly synthesized from hydro-carbons, nitrogen and other elements. They either remain outside the biotic components as reservoir pool or may be acted upon by microbes to be available to the living organisms in the form of cyclical pool.

- [ii] Biotic components: The living components of an ecosystem are mainly of two types, (a) Autotrophs (b) Heterotrophs.
- (a) Autotrophic components: The autotrophic components of an ecosystem can prepare their own food either by the process of photosynthesis or by chemosynthesis. These foods are primarily carbohydrate, but the other forms of food viz. fat and proteins are also systhesized and they are available to the heterotrophs.
- (b) Heterotrophic components: The heterotrophic components cannot prepare their own food, so they depend directly or indirectly on the autotrophs. They include the primary and secondary consumers on one hand and also the decomposers or the saprophytic organisms, which cause decay of the dead plants and animals and help in the recycling of nutrients.

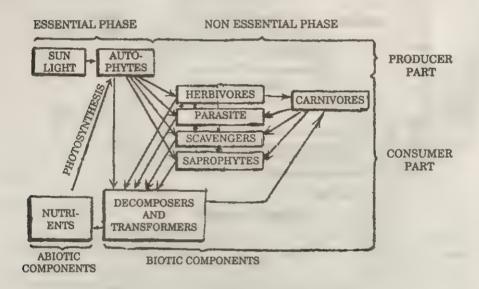


Fig. 13.2: Different phases and components of ecosystem

- [4] Types of Ecosystem: Ecosystems can be classified on the basis of the region where it has developed like pond ecosystem, grassland ecosystem, desert ecosystem and forest ecosystem. But broadly they are of two types, (a) Natural or Macro ecosystem (b) Artificial or Micro ecosystem.
- (a) Natural ecosystem: They are large in size and also called macro ecosystems and can be classified on the basis of the total energy flow as per Odum (1975).
- (i) Natural solar powered ecosystem like forests, grasslands, lakes with an energy flow of 1000 to 10,000 K. Calories.
- (ii) Nature subsidised solar powered ecosystems like tropical rain forest, tidal estuaries with an energy flow of 10,000-40,000 K. Cal.
- (iii) Man subsidised solar powered ecosystems like agriculature with energy flow 1000-40,000 k. cal.
- (b) Artificial ecosystems: They are purely man-made and independent of solar energy. They are also called micro-ecosystems and are prepared to study the inter-

relationship between various components in laboratory conditions. e.g. aquariums, laboratory cultures.

- [5] Sturcture of Eco-system: The ecosystem has 4 major components structurally, which are (a) Abiotic components (b) Producers (c) Consumers and (d) Decomposers.
- (a) Abiotic components: They are the morganic and organic components present in the air, water and soil, they either remain in the abiotic phase or they are absorbed by plants and thus enter the biotic phase. After the death and decay of the biotic organisms, they are returned back to the nature.
- (b) **Producers**: They include all the autotrophic organisms, which can prepare their own food utilizing carbon dioxide, water and mineral salts form the atmosphere. They include the following organisms:

(i) Photosynthetic bacteria: They have chlorophyll and can prepare food with the

help of solar energy. e.g. green sulphur bacteria.

(ii) Chemosynthetic bacteria: These bacteria are devoid of chlorophyll but can prepare their food by the oxidation of inorganic substances like ammonia, nitrites or ferrous carbonate etc. e.g. Nitrosomonas, Nutrococcus etc.

(iii) **Phytoplanktons**: The floating green plants which may be microscopic like the green algae *Volvox* or macroscopic like *Lemna* and they are major producers of all aquatic ecosystems.

(iv) Land plants: They include all the herbs, shrubs and trees and provide energy

for the running of all terrestrial ecosystems.

(c) Consumers: The consumers are heterotrophic organisms which cannot prepare their own food, but depend on the producers for their nourishment.

There are different types of consumers depending upon their feeding habits and

they are as follows:

- (i) Primary or Ist order consumers: They are herbivores and directly feed on green plants. They include zooplanktons like protozoa, Daphnia, benthonic or bottom feeders like snails, arthropods, insects like grasshoppers, birds and mammals like rabbit, dear, cow etc.
- (ii) Second or 2nd order consumers: These animals feed on primary consumers. Elton (1939) referred to these primary carnivores as key industry animals. They include the frogs and fishes in grassland and pond ecosystem. Wolves, tigers, moles can also serve as secondary consumers in terrestrial ecosystems.

(iii) Tertiary or 3rd order consumers: They are upper graded consumers which

feed on secondary consumers.

They are the upper graded consumers in an ecosystem, snakes in grassland ecosystem are tertiary consumers but the peacocks form the final consumers, sharks form the tertiary consumers in ocean ecosystem, eagles can also serve as tertiary consumers in terrestrial ecosystems.

[d] Decomposers: The heterotrophic organisms like fungi and hacteria, which break down complex organic macromolecules of dead organisms to comparatively

simpler substances are called decomposers.

They convert complex organic substances to simple inorganic forms and hence they are also called **reducers** or **microconsumers**. The simpler substances can also be absorbed by the micro-organisms and they produce secondary metabolites like vitamins and antibiotics and they are broadly termed as **ectocrines**.

Functions of Decomposers: (i) Production of food. (ii) Recycling of nutrients by mineralization of dead organic tissues. (iii) Production of ectocrine materials.

In this way, the producers, consumers and decomposers are considered as three functional kingdoms of nature, which interact closely with the abiotic factors.

13.3.1. FOOD DEPENDENT RELATIONSHIPS OF ECOSYSTEM AND TROPHIC LEVELS:

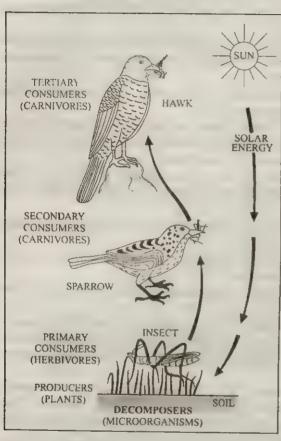


Fig. 13.3: Biotic components of ecosystem

The food dependent relationships are observed in various levels of ecosystem. The producers are responsible for the production of food and the consumers obtain it directly or indirectly form the producers. The primary consumers directly feed on the producers, while the secondary consumers (carnivores) feed on the primary consumers, but each of these pairs constitute a foodpredator relationship. After the death of the producers and consumers, the decomposers act on them and cause their decay and decomposition. In the ecosystem, the producer-consumer arrange-ment represent a trophic structure and each of the levels are called trophic levels. Each trophic level is represented as the biomass or the number of organisms per unit area. The producers occupy the first trophic level, the herbivores remain at the second trophic level: the carnivores remain at the third trophic level, the secondary carnivores occupy the fourth trophic level. At each level the biomass decreases and they remain

in the form of a pyramid.

13.3.2, FOOD CHAIN

Definition: The linear food-predator relationship exhibited by a series of organisms in an ecosystem is termed as food chain.

In the ecosystem, the solar energy is trapped by the producers by the process of photosynthesis and the plant food is systhesized, which is transferred to the primary consumers, then to secondary consumers and tertiary consumers. At the last step, an appreciable amount of energy (80%) is lost as heat, though even then, the food chain is not disrupted because the biomass goes on reducing as higher consumers are approached in an ecosytem.

The food chain observed in a pond ecosytem is quite simple and includes four steps and they are as follows:

Step I -> Step II Step III Step IV Phytoplanktons Zooplanktons Fishes Insects (Tertiary consumers) (Primary consumers) (Secondary consumers) (Producers)

In case of a grassland ecosystem, the food chain is little longer having five major steps and it goes like this.

Step I Step V Step II Step IV Amphibians Peacock Grasses Insects Snakes (Primary consumers) (Secondary consumers) (Tertiary consumers) (Final consumers) (Producers)

- [1] Types of Food Chain: There two types of food chairs. viz. [A] Grazing food chain; [B] Detritus food chain.
- [A] Grazing food chain: The food chain comprising of green plants as producers, herbivores as primary consumers, carnivores as secondary consumers and terminated in secondary carnivores is known as grazing food chain. It is also termed as predator chain since it represents simple food-predator relationship. Here the food is synthesized by producers may be (1) eaten by herbivores, (ii) utilized in respiration or (iii) stored within their body. The carnivores obtain the energy from the herbivores, assimilate it within their tissue and utilize it partially by respiration. The food chain of a grassland ecosystem is an example of grazing food chain, where 50 percent of the annual net production, passing down the grazing herbivore, flow in this path.

[B] Detritus food chain: The food chain comprising of detritus organisms growing on dead organic wastes is known as detertus food chain.

The organisms feeding on detritus (organic matter) are known as deterivores or detritus consumers. They constitute the detritus food chain. They represent a significant component of energy flow in an ecosystem. In a normal temperate forest ecosystem, only 10% energy passes along the grazing food chain, while the remaining 90% passes along the detritus food chain.

Characteristics of detritus food chain:

- (i) Maximum energy flows through the detritus food chain.
- (ii) Major part of this energy is stored without the detritus itself, outside the detrivores.
- (iii) The energy flow in detritus food chain is a continuous process and not a stepwise process as observed in grazing food chain.

Organisms of a detritus food chain: The algae, fungi, bacteria, protozoa, insects, molluses, crustaceans, annelids and nematodes may all constitute a detritus food chain. They normally ingest the decomposed organic matter, digest them partially and excrete the undigested remains in the form of humus, that makes the soil fertile. Sometimes these organisms can also survive in living host and constitute a parasitic food chain.

13.3.3. FOOD WEB

The food chains remaining in an interconnected state forming a complex, branched

state is known as food web.

The food web is regarded as a complex of food chains, they may include different types of plants, different types of primary consumers like grasshoppers, birds, deer, snails and rats. The herbivores are eaten up by different carnivores like frog, snakes, tigers. The secondary carnivores like lions, tigers feed on the primary carnivores. But at this level, they show various degree of predation, that is the lion feed on rabbit, deer and cattle, the snakes feed on rabbit, the snake may be fed upon by hawk, while birds feed on insects and sometimes rats. So, when all these interrelationships are studied, the resulting figure will be a complex, branched arraegation of food chains, referred to as **food web.**

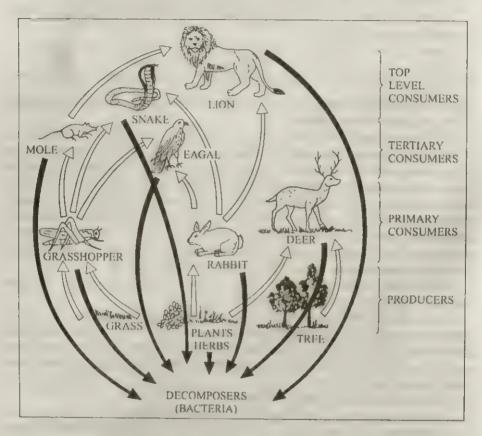


Fig. 13.4: Multiple food chains constituting food web

13.4. Ecological Pyramids:

The pyramidal representation of an ecosystem denoted by Charles Elton (1927) is known as Ecological pyramid. It is also called Eltonian pyramid. It represents the position of the producers and successive consumers in an ecosystem. The producers remain at the base of the pyramid, then the primary, secondary and tertiary consumers remain one on top of the other. Their arrangement is strictly on the basis of food predator relationship as seen in a food chain. The biomass of the predators is gradually reducing but their size gradually increases as they move into higher trophic levels.

13.4.1. TYPES OF ECOLOGICAL PYRAMID:

Elton donoted three types of ecological pyramids, which are as follows:

[1] Pyramid of numbers: The numerical relationship between members of different trophic levels in an ecosystem constitutes the pyramid of numbers. In general, the number of producers is maximum and gradually the number of herbivores and carnivores

are reduced. So, the pyramid shows a progressive reduction in the number of the organisms from base to the apex. Thus for a pond ecosystem, the phytoplanktons and algae are greastest numbers, the aquatic insects feeding on them are less than these producers. The small fishes at the third trophic level are even less than that, while the larger fishes are minimum in number and occupy the extreme top position of the ecological pyramid. The **pyramid of number** may be inverted in certain cases, where the producer is a big tree and primary consumers are small insects.

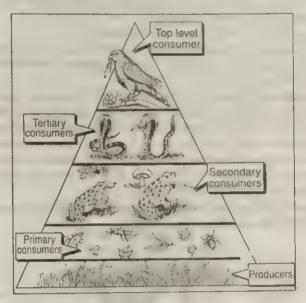


Fig. 13.5 1 Pyramid of numbers

[2] Pyramid of biomass: The total dry weight of the organisms present in particular trophic level is known as biomass. The ecological pyramid based on the biomass is known as the pyramid of biomass. Like the pyramid of numbers, this also shows progressive reduction in the bio-mass of organisms from the base to the apex of pyramids. For the terrestrial ecosystems, like forest ecosystem, the pyramid is upright, but the pond ecosystem shows an inverted pyramid of biomass because the biomass of producers are much less than that of the consumers.

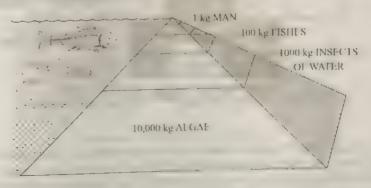


Fig. 13.6 : Pyramid of Biomass

[3] **Pyramid of energy:** The ecological pyramid depicting the flow of energy between the members of a ecosystem at different trophic level is known as pyramid of energy. The energy trapped by the producers is highest and it is gradually reduced as it passes to the tertiary consumer. Thus, if energy at each trophic level is substantial, then the slope of the pyramid is gradual.

13.5. Energy Flow in Ecosystem

The linear unidirectional flow of energy from the producers to the final consumers constitute energy flow in an ecosystem.

The various stages of energy flow are as follows:

- [1] Energy fixation by producers: Only a small amount of solar energy encountered by the plant can actually be utilized during photosynthesis, where the solar energy is converted to chemical energy.
- [2] Accumulation of energy by the producers: The energy accumulated by the producers can be calculated by biomass estimation. According to Edger Transeau (1926), a total weight of crop plants of 6000 kg comprising 10,000 plants can assimilate 2675 kg of carbon = 6687 kg of glucose, it is termed as Net Production (N.P.), the amount of carbon relased in the form of carbon di-oxide during respiration (R) is 2045 kg. Therefore gross production = (NP) + (R) = (6687 + 2045) kg = 8732 kg. One kg of glucose production requires 3760 kilo calories of energy.

So 8732 kg of glucose production will require 33 million kilo calories of energy coming from 2043 kilo calories of solar energy.

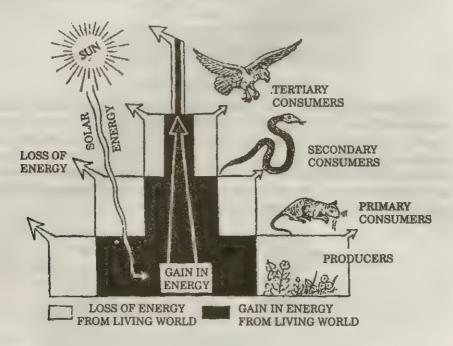


Fig. 13.7: Energy flow in an ecosystem

[3] Energy Flow from producer to primary consumer: Raymond Lindemann (1942) gave a well documented flow sheet indicating the amount of energy flowing in an ecosystem and how much energy remains unused in an ecosystem on the basis of gm claorie per square cm. per year.

Lindemann's Data:

Zimeom o z mon v							
						al./cm²/yr.	
(i) Incident solar radiation	12.			,	1	18,872.00	
(ii) Net production (N.P.)	41 , 1	,	Trip		. (1	, 87.90	
(iii) Utilization of respiratory energy (R)						25.40	
(iv) Gross production (G.P.)						113.30	

Thus out of 118,872 gm. cal/cm²/yr, only 113.3 gm cal/cm²/yr., that is 0.1% energy is utilized. Moreover, out of 113.3, only 25.4 gm cal/cm²/yr that 21% energy is utilized by the producers during respiration and other metabolic activities. The primary consumers can utilize only 15 gm cal/cm²/yr, and 17% is lost. Of that energy, 5 gm cal/cm²/yr, is utilized during respiration of hervivores. The remaining 10 gm cal/cm²/yr, is available, rest 70% remain unused. Of the total energy entering the secondary consumer, 60% (1.8 gm cal/cm²/yr) is utilized during respiration, while the rest 40% remains unused and finally lost. It was also observed that 3.4% of the energy is lost during decomposition. Only 79.5% of NP of the autotrophs that is 70 gm cal/cm²/yr is deposited in the soil.

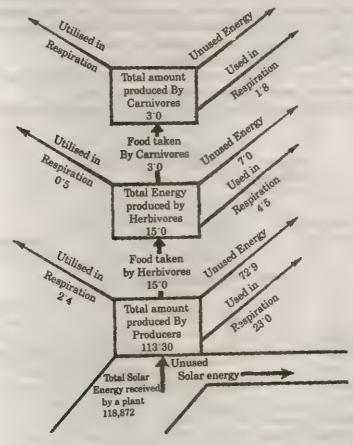


Fig. 13.8: Energy flow sheet (Lindermann 1942)

In order to explain the lost energy in each tropic level, ten percent law gives the simplest explanation, that is each organism at a trophic level can only utilize $^{1}/_{10}$ th of

the total food consumed. Thus, a deer consuming 100 kg of food utilized 10 kg only, while a tiger eating 10 kg of flesh could utilize only 1 kg.

- [4] Characteristics of Energy Flow:
- (i) Solar energy is the sole source: The solar energy is the only source of energy in an ecosystem utilized by the green plants by photosynthesis.
- (ii) **Energy flow is unidirectional:** The energy flow is strictly unidirectional from producers to the tertiary consumers and cannot return to the solar system. It can only be reverted back after the decomposition process is completed.
- (iii) Gradual decrease in energy flow: The energy flow is reduced substantially (minimum loss may be 10%) and maximum loss may be upto 90% at each trophic level due to utilization of energy for respiration and other metabolic activities of living species at each trophic level.

13.6. Blo-geochemical Cycle:

The cyclic movement of chemical elements of the biosphere between the organism and the environment is known as biogeochemical cycle. The term was coined by Vernadsky (1934). It has two major phases, that is the biotic phase meaning living organism and geologic phase meaning rock, soil etc. The cycles with dominant atmospheric phase is known as atmosphere-reservoir cycle and those with dominant sedimentary phase is known as sediment-reservoir cycle.

13.6.1. TYPE OF BIOGEOCHEMICAL CYCLE:

There are three major types of biogeochemical cycles. They are water or hydrological cycle, gaseous cycles and sedimentary cycles.

(i) Water cycle: The cycle mainly involves transfer of ground water to water vapour

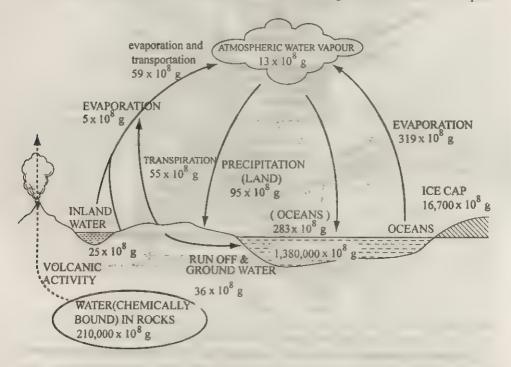


Fig. 13.9: Water cycle

of the atmosphere by evaporation or through transpiration by plant. The atmospheric water vapour is returned back to soil by precipitaton.

- (2) Gaseous cycles: They include mainly the carbon cycle, oxygen cycle and the nitrogen cycle.
- (a) Carbon cycle: It mainly involves the fixation of atmospheric carbon di-oxide by green plants during photosynthesis, its storage as carbohydrate food and its transfer to animal. It is returned back to atmosphere during decay and respiration by plants and animals. Apart from that, the combustion of fossil fuel also returns back the carbon di-oxide to atmosphere.

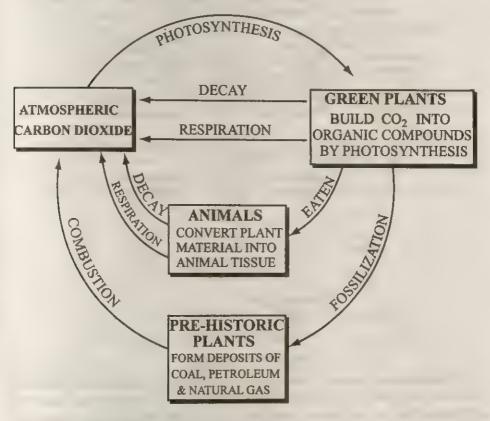


Fig. 13.10: Carbon cycle

(b) Oxygen cycle: It is virtually the reverse process for carbon cycle, by which oxygen is removed from atmosphere during respiration and returned back to atmosphere by the photosynthetic activity of green plants.

(c) Nitrogen cycle: The cycle involves cyclic transfer of nitrogen between the atomospheric nitrogen and soil nitrate. The atmospheric nitrogen is removed from the atmosphere by the process of nitrogen fixation by free living or symbiotic bacteria. It is a major component of the structural protein of plants and animals. After the death and decay of plants and animals, the nitrogen is returned back to soil by bacterial decay through the processes of ammonofication and nitrification. Another group of bacteria (Pseudomonas) can return back soil nitrate as gaseous nitrogen through denitrification.

Apart from that, atmospheric nitrogen can directly get dissolved in rain water and come down to soil during lightning flash.

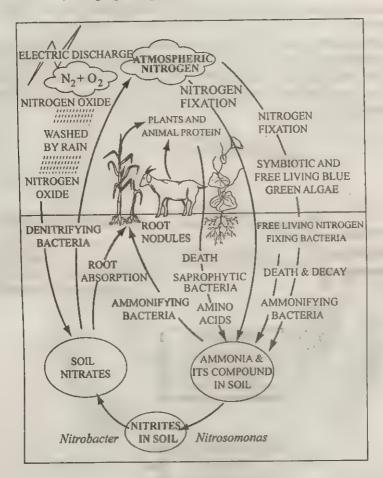


Fig. 13.11: Nitrogen cycle

(3) Sedimentary cycles: These cycles involve transfer of sedimentary minerals from rocks and marine sediments as dissolved salts into the living organisms and they are returned back to the abiotic phase after the death and decay of these plants and animals. These cycles include the sulphur cycle and phosphorus cycle.

13.7. Biosphere:

Biosphere is the portion of lithosphere (rock), hydrosphere (water) or atmosphere (air), where life can exist. It is like a huge ecosystem, where the living and non-living components interact in close proximity. Biospheres are getting degraded due to increase in population pressure, deforestation and industrialization. This increasing damage causes loss of biodiversity both in terms of flora and fauna. Conservation of biosphere is brought about by Biosphere Reserve.

13.7.1. BIOSPHERE RESERVE

Definition: Biosphere reserves are undisturbed areas meant for scientific study, where human interferences are under control.

The movement of designating biosphere reserve was launched by UNESCO in 1973 as a part of the "Man and Biosphere" programme and is considered to be the most effective means of protecting the ecosystem.

[1] Objectives of Biosphere Reserve:

(i) Conservation of biotic diversity.

- (ii) To protect the genetic diviersity, so that evolution can act in the normal way.
- (iii) To provide a natural area for research in ecology and environmental biology and promote environmental education.
 - (iv) To promote international co-operation.
 - (v) To provide a method for sustainable management of biotic resources.
 - [2] Minimum criteria to be fulfilled by a Biosphere Reserve:
 - (i) They should belong to definite geographical province.
 - (ii) They should have adequate genetic diversity in terms of flora and fauna.
 - (iii) They should have an adequate area to ensure conservation.
 - (iv) To have long term legal protection to flora and fauna.
 - [3] Description: A biosphere reserve consists of 3 major areas:
- (i) The Core Zone: The innermost central zone is termed as the core zone or Sanctum sanctorum; it is protected from non-native plants and animals and there is no human interference.
- (11) Buffer Zone I and II: The buffer zone surrounds the core zone. The buffer zone I may indicate some sort of human interference in a controlled manner. The buffer zone II may have an experimental station for carrying out research activities.
 - (iii) Manipulation Zone: The outermost broad area surrounding the buffer zone

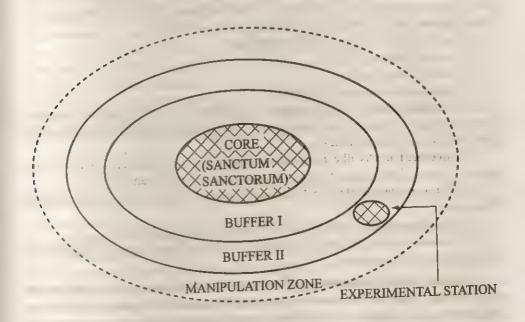


Fig. 13.12: A model of Biosphere Reserve

is called manipulation zone. It may include the forestry zone, tourism zone, agricultural zone and the reclamation zone.

Till 1989, there were 337 biosphere reserves in 68 different countries of the world including 14 form India. As per the advice of the central advisory committee (1979), the first Indian biosphere reserve came up in the Nilgiris in 1986 comprising of Tamil Nadu, Kerala and Karnataka. The other biosphere reserves in India are Namdapha (Arunachal Pradesh), Nanda Devi (Uttaranchal), Valley of flowers (Uttaranchal), North Andaman Islands, Gulf of Manner (Tamil Nadu), Kaziranga (Assam), Sundarbans (West Bengal), Thar desert (Rajasthan), Manas (Assam), Kanha Kisli (M.P.), Nakrok (Meghalaya), Little Rann of Kutch (Gujarat), Great Nicobar Island.

13.7.2. SUNDARBAN AS BIOSPHERE RESERVE:

The Sundarbans is located in the southern most part of West Bengal in the active delta forming region of Bhagirathi-Hooghly river and its tributaries like Damodar, Rupnarayan in the west and Ichamati river in the east. The soil contains high amount of sodium, potassium and magnesium salts and so it is called the physiologically dry soil. The vegetation is essentially mangrove type, where the major tree is *Heritiera fomes* or Sundari, from where the name Sundarbans has been derived. Apart from that other plants like *Rhizophora mucronata* or Garan, *Ceriops tagal* or Hental are common. The fauna include the *Panthera tigris* or Royal Bengal tiger, marshy crocodiles, leopard cats *etc*.

- (i) Area: The total area is 9630 sq. km., of which 4246 sq. km is under reserve forest. It has one National Park, a tiger reserve and three wild life sanctuaries like Sajnekhali, Haliday island and Lothian island.
- (2) Flora of the Sundarbans: The Sundarbans has 26 of the 53 different mangrove plant species growing in it. According to **David Prain** (1932), the mangroves of Sundarban can be divided into three distinct regions, which are
 - (i) Southern coastal trip or South western part.
 - (ii) Central Zone of Heritiera.
 - (iii) North Eastern part.

The major plant specimens include:

- (i) Evergreen shrubs like Avicennia alba (Verbenaceae), Rhizophora mucronata, Bruguiera gymnorhiza (Rhizophoraceae), Sonneratia apetala (Sonneratiaceae), Heritiera fomes (Sterculiaceae).
- (ii) Succulent herbs like Excoecaria agallocha (Euphorbiaceae) with a semi-parasitic species growing on it called Loranthus articulata (Loranthaceae).
- (iii) Non-succulent herbs like Acanthus ilicifolius (Acanthaceae), Carapa abovata (Meliaceae).
 - (iv) Saline palms like Nipa fruticans, Phoenix paludosa (Palmae).
- (v) Grasses like salt-tolerant Oryza sativa, var Achra, Oryza coarctata (Graminae), Scirpodendron (Cyperaceae).
- (3) Fauna of the Sundarbans: The fauna of the Sundarbans also exhibit widest of diversity in cluding 106 species of protozoa, 998 species of invertebrate including 262 species of crustacea, 481 vertebrate species including various economically important species like Hilsa (*Tenulosa ilisha*), Bhetkı (*Lates calcarifer*), Bhangone (*Liza tade*), Parse (*Liza parsia*).

In the nineteenth century, some important species like the Java Rhinoceros (Rhinoceros sondaicus), wild buffalo (Bubalus bubalis) have disappeared. In the recent years the swamp deer (Cerries divaucelli) have become extinct. According to the Red Data Book of ZSI (1993), the major endangered species of the Sundarbans are as follows:

(i) Reptiles:

Estuarine crocodile - Crocodylus parosus. Olive Ridley turtle - Lepids chelys olivacea. Yellow monitor - Varanus salvar Common Indian monitor - V. bengalensis.

(i) Birds:

Giant Heron - Ardea goliath Dalmation Pelican - Pelecanus philippensis

(iii) Mammals:

Leopard Cat - Felis bengalensis. Fishing Cat - Felis viverina. Royal Bengal tiger - Panthera tigris. Barking deer - Muntiacus muntijac

Chinese pangolin - Manis pentadactyla Gangetic dolphin - Platanista gangetica.

13.8, Environmental Pollution

Now a days the term pollution has become quite familiar to us. It is generally used to denote environmental pollution, which means changes in the environment are adversely affecting us. In the past, the environment was pure and clean but with the explosion of population, advancement of technology and industrial revolution, our environment is becoming more polluted day by day in different ways. Pollution is a man-made problem that disturbs the natural ecological balance, as a result of which the existence of the living world is in danger. Thus, the pollution problems is a curse of science and modern civilisation. At present the human life in the whole world is so adversely affected by this problem that most of the countries have started research investigations regarding the cause, harmful effects and prevention of different types of pollutions. For this reason, pollution has been added as a new chapter in modern biology.

Definition of pollution: Pollution has been defined in various ways, of which a

few important ones are given below:

[1] According to Odum (1971) - Pollution is an undesirable change in the physical, chemical or biological characteristics of the environment that may harmfully affect man and other desirable species of living organisms.

[2] According to Southwick (1976) - Pollution is the unfavourable alternation of

the environment produced as a result of the activities of man.

[3] According to World Health Organisation (WHO) - Pollution is a phenomenon in which the environment becomes hazardous for human health due to an abnormal increase or decrease of its natural components or entry of extraneous materials into it.

Origin or cause of pollution: From the views forwarded by modern ecologists regarding the origin of pollution, it is apparent that the chief reasons behind pollution are the following:-

[1] Continuous growth of population; [2] Unscientific and unplanned urbanisation and industrialisation; [3] Random deforestation and killing of animals; [4] Misuse of science and technology by man for the sake of economic prosperity and capitalistic mentality.

13.8.1. POLLUTANTS

The materials causing pollution of the environment (i.e. the polluting agents) are called pollutants.

Classification of Pollutants: Pollutants can be classified in three ways as follows:

- I. According to their nature, pollutants are of three types chemical, physical and biological.
- [1] Chemical pollutants: Various solid, liquid and gaseous chemical agents may pollute the environment. Some such common chemical pollutants are as follows:
 - (a) Gases, fumes and dusts; example CO₂, CO, SO₂, NH₃, Cl, F etc.
 - (b) Deposited materials, e.g. smoke, fog, smog, soot, tar, dirt etc.
- (c) Chemicals used in agriculature, e.g. herbicides, pesticides, insecticides, fertilizers etc.
 - (d) Metals, e.g. lead, mercury, zinc, cadmium etc.
 - (f) Sewage.
- (g) Narcotics and drugs e.g. morphine, nicotine, heroine, LSD, alcohol, marijuana etc.
 - (h) Other chemicals such as aldehydes, arsines, hydrogen flourides etc.
- [2] Physical pollutants: The physical agencies that can produce harmful effects on our body are listed below:
 - (a) Sound or noise.
 - (b) Solar rays (ultraviolet and infrared).
 - (c) Heat.
 - (d) Electric shock.
 - (e) Ionizing radiation (X-rays, γ -rays etc.)
- [3] Biological pollutants: Many living materials are injurious to human health; hence, these are considered as biological pollutants. Examples are pathogenic microbes such as virus, bacteria, protozoa, fungi etc. Certain other materials produced by the living organisms e.g. pollens, spores, snips of hair, textile fibres, excreta of mites and other animals etc. also pollute the environment.
- II. From ecosystem viewpoint, Odum classified the pollutants according to their stability or persistence in the environment into two types-degradable and non-degradable.
- [1] Degradable pollutants: These pollutants are easily degraded (i.e. less stable) and do not persist in the environment for a prolonged period. Certain chemicals (e.g. aldehydes, sewage), noise (sound) etc. belong to this group. They become dangerous, when their input in the environment exceeds their removal.
- [2] Non-degradable pollutants: The pollutants that are degraded or decayed very slowly are admitted to this group. Naturally, the harmful effects of these agents are more severe, prolonged and far reaching. Examples are salts of mercury and aluminium; pesticides like aldrin, DDT (Dichloro diphenyl trichloroethane), gammexane; phenolic compounds, plastic and polythene materials etc.

III. According to their origin and formation i.e. on the basis of the form in which they exist in the environment, pollutants are also classified into two types - primary pollutants and secondary pollutants.

[1] Primary pollutants: These are pollutants which exist as such after being added or released into the environment. So, they are added directly to the environment. Examples are—gases like oxides of sulphur, nitrogen, and carbon; dusts; microbes and

toxic chemicals like pesticides, heavy metals etc.

[2] Primary pollutants: These are the pollutants formed by reactions between primary pollutants and other components of the environment after the primary pollutants are released in the environment. So, they are not directly released from a source, rather they are produced in the environment. Examples are smog, acid rain, peroxy acetyl nitrate (PAN) etc.

13.8.2. TYPES OF POLLUTION:

The common pollution problems that we have to face can be classified in three ways -

I. According to the component of the environment which is being polluted; for example [1] air pollution, [2] water pollution and (3) land (soil) pollution.

II. According to the physical nature of the pollutant; for example -

[1] gaseous pollution, [2] dust pollution, [3] noise pollution, [4] thermal pollution, [5] radioactive pollution etc.

III. According to origin: Pollutions can be classified into two broad groups

natural and artificial or anthropogenic (man made).

[1] Natural pollutions are those which originate from natural process e.g. forest fire, volcanic erruptions, dust storms, natural organic and inorganic decays, release of microbes, pollens, spores etc.

[2] Artificial or anthropogenic pollutions are those which originate due to activities of man, for example industrial pollution, agricultural pollution, automobile pollution,

domestic pollution etc.

The anthropogenic pollution are the major problems because they are increasing day by day due to overpopulation. Among the various man-made pollution problems, the largest ones are air pollution, water pollution, soil pollution, noise pollution and radioactive pollution because these are very common (i.e. frequently occurring) and they produce deleterious effects on vast populations.

13.8.3. AIR POLLUTION

Definition: Any adverse change in the composition of atmosphere which occurs due to the activities of man or some natural event and endangers human life is called air pollution or atmospheric pollution.

Air is one of the most important components of the environment and is essential for life, because no living organism can survive without it. Like most other living beings, man is also dependent on oxygen of atmosphere for respiration. Therefore, if the concentration of O2 in air is reduced from normal due to the increase in concentration of any other undesirable gas (e.g. CO, CO₂, SO₂, NH₃, Cl₂, CH₄ etc.), the air is said to be polluted and the phenomenon is designated as air pollution. Air pollution is very dangerous because the polluted air can easily spread from one place to another and affect a large population.

Sources or causes of air pollution:

Sources of air pollution may be **natural** or **anthropogenic**. The **natural sources** include—forest and volcanic erruptions (that liberate smoke, poisonous gases and ashes), dust storms, pollen grains of flowers, fungal spores and microbes *etc.* carried by air. All these are produced naturally and released in air, making it foul and injurious to human health.

The anthropogenic sources of air pollution include the following:

[1] Industries: Industries such as metallurgical plants, power plants and smelters, chemical plants, petroleum refineries, paper and cotton mills etc. release various inorganic or organic gases in the smoke they produce. In addition, some industries release small particles of dust, carbon, metals etc. and ashes that remain suspended in air. All gases and suspended particles are harmful for human health.

[2] Emissions from vehicles: Transport vehicles moving by road, rail, water or air using fossil fuels (coal or petroleum oils) produce smoke containing poisonous gases and contribute to air pollution. Automobile emission is a serious problem for cities

having heavy traffic on the roads.

[3] Domestic and institutional sources: Burning of wood or fossil fuels in furnaces and stoves, or running of diesel generators in houses or institutions (hotels, offices, schools, colleges *etc.*) also produce smoke and pollute the air. Tobacco smoking is also an important source of air pollution in public places like offices, institutions and public transports.

[4] Agricultural activities: Different types of biocides (e.g. pesticides, insecticides, fungicides, herbicides etc.) are used for spraying in agriculture. These poisonous materials remain suspended in air and carried away by the wind making the air foul for

human health as well as for other animals.

[5] Nuclear explosions and wars: They emit radioactive rays that are very harmful for mankind.

[6] **Deforestation**: Plants purify the air by removing CO_2 and adding O_2 during the process of photosynthesis. Deforestation, *i.e.* indiscriminate cutting of plants, trees and cleaning the forests by man for getting wood or urbanization leads to increase in CO_2 and decrease in O_2 in the atmosphere, causing air pollution.

Air pollutants and their sources:

Air pollutants may be **primary** (that are released directly from the sources) or **secondary** (that are formed in atmosphere) in origin. The primary air pollutants include **poisonous** (or harmful) **gases** and **particulate matters** or **aerosols** (solid particles or liquid droplets that are small enough to remain suspended in air). Example of pollutant gases are oxides of carbon, sulphur and nitrogen, hydrocarbons, halogens *etc.* Common particulate matters polluting the air are — smoke, dusts, ashes, fibres, pollens, spores, biocides and some metals. Secondary air pollutants include smog, ozone, PAN and acid rain. The common and major air pollutants and their sources are described below.

[1] Smokes and gases: The chief cause of air pollution is mixing of various types of smokes and gases with the air. Smoke is formed by combustion of fuels. It contains various poisonous gases, carbon particles and harmful compounds that pollute the air. Smoke originates from three major sources, e.g. automobiles, factories and furnaces. The smoke originating from incomplete combustion of fuels e.g. diesel, petrol and

coal in automobiles and vehicles contain poisonous gases like **oxides of carbon** (CO₂ and CO), **sulphur dioxide** (SO₂), **oxides of nitrogen** (NO and NO₂), and **hydrocarbons**. Automobile using leaded petrol or gasoline adds lead (Pb) to the atmosphere, unleaded petrol adds benzene vapour. Smoke emitted by the chimney of **factories** also contain the above mentioned poisonous materials originating from combustion of fuels. Sulphur dioxide originates from burning of fossil fuels or smelting of metallic ores (in smelters) having sulphur impurities. Moreover, some industries emit ammonia, chlorine, fluorine, benzopyrene *etc.*, which are harmful for us. **Furnaces** and **stoves** used for **domestic**



Fig. 13.13: Pollution of air by smoke.

and other purposes also add smoke to the atmosphere due to burning of wood, coal, kerosine etc. in them. Now a days, the widespread use of diesel generators has become a very common cause of smoke nuisance especially in urban areas. Halogenated organic chemicals such as **chlorofluoro carbons** (CFSs) are used in refrigeration, spray propellants, foaming agents and jet planes. The CFCs diffuse into the atmosphere and cause pollution (destroy the ozone layer of atmosphere). Methane (CH₄) a hydrocarbon gas polluting the air, is evolved from marshy lands and flooded paddy fields by putrefaction of weeds and crop residues.

The atmospheric sulphur di-oxide and nitrogen oxides are highly reactive in air. In presence of oxygen and water vapour, they form sulphuric acid and nitric acid respectively. These strong acids are highly soluble in water and are carried down to the earth with rainfall, which is referred to as acid rain. The acid rain is a secondary pollutant causing economic hazard to the mankind.

Air pollution may also be caused by accidental gas leaks from the factories in which a poisonous gas is either stored for use or produced as a by-product. Although such accidents occur very rarely, their impact on mankind is extremely dangerous. Perhaps nobody has forgotten the recent disastrous incident of gas leak in our country, which occurred in December 1984. In this, a large number of people were killed and many more were seriously affected by a very poisonous gas called methyl isocyanate (MIC), that leaked from a factory at Bhopal in Madhya Pradesh.

Tobacco smoking should also be considered as a source of air pollution. It affects not the smoker himself but also his fellow beings, who inhale the smoke passively. The smoke of tobacco and allied materials contain poisons like carbon monoxide,

nicotine and benzopyrene.

[2] Fog, Dust and Smog: The air contains dusts of various materials like lead, mercury, silica, asbestos etc. These dusts and fog make the air heavier. Particularly in winter, when the fog is increased, it combines with smoke and dust particles to form a dense, blackish layer in the lower part of the atmosphere (troposphere); this is called smog. Nitrogen oxides and hydrocarbons of the atmosphere react in presence of UVrays of sunlight to form ozone gas and some poisonous materials like peroxyacetyl nitrate (PAN), aldehydes etc. These chemicals produced by the photochemical reactions in the atmosphere collectively form the photochemical smog, which is an important secondary pollutant. It is often called brown air, where solar radiation is intense. In areas or seasons of lesser solar radiation, smog formation is incomplete and the air is referred to as grey air.

Although the ozone gas present in the stratosphere (upper part of atmosphere) acts as a shield protecting the earth from excess UV rays of the sun, presence of ozone in photochemical smog in the troposphere (lower part of atmosphere adjacent to earth surface) acts as a pollutant because it is injurious to plant and animal tissues. The photochemical smog is formed in traffic congested cities due to excessive smoke

emission from automobiles.

[3] Biocides: Various biocides (chemicals used to kill unwanted living organisms) like pesticides, insecticides, herbicides, fungicides, rhodenticides etc. are widely used in agriculture and storage of food. These chemicals are generally dissolved in oil or water and then sprayed on plants, crops or vegetables. During spraying, these toxic materials diffuse into air as aerosols and pollute the air. Some of these are strong irritants and have a pungent smell. Thus, the air pollution caused by these chemicals mainly affect those people who are engaged in agriculture and use them. Such toxic agents may also affect other people by causing food and water pollution.

[4] Living organisms: Many biological pollutants such as bacteria, virus, spores of fungi, pollen grains etc. that are harmful for human health remain suspended in air. Recently the pollens of a rapidly growing weed called Parthenium has been shown to

cause allergy in man by spreading through air.

[5] Radioactive elements: Atomic research, atomic explosion and ashes of nuclear furnaces add radioactive elements to the atmosphere. The radioactive rays emitted by them produce harmful effects on living beings. Random use of X-ray and over-exposure to it, is also detrimental to human health.

[6] Solar rays: Solar ultraviolet and infrared rays are harmful if present in excess. The CO₂ present in air absorbs infrared rays as a result of which the temperature of earth is raised. So, an abnormally high level of CO₂ in air creates unfavourable situation for the living beings due to an unusual increase in earth temperature (green house effect); it may even cause a deluge by melting of ice in the polar regions.

Harmful effects of air pollutions:

Air pollution adversely affects the mankind directly by causing health hazards and indirectly by affecting the vegetation, livestock, climate, buildings and assets as described below briefly.

[A] General hazards of air pollution (or indirect effects of air pollutions on man):

[1] Loss of clarity of the atmosphere due to the presence of dust, smoke and smog resulting in reduced visibility and severe accident on roads or rails.

[2] Soiling of clothes, buildings and other goods by soot, dust and smoke.

[3] Offensive odour and asthetic insult due to certain gases present in air.

[4] Reduced soil fertility by acid rain and spoilage of agricultural crops by SO₂, fluorides, ethylene, acetylene, photochemical smog etc.

[5] Destruction of forests and terrestrial plant species due to excess of oxides of sulphur in the air and acid rain. Destruction of aquatic plants and animals by acid rain.

[6] Corrosion of metals and marbles in buildings and national monuments due to acid rain and ozone of smog.

[7] Increase in global temperature due to 'green house effect' of CO2.

[8] Skeletal and dental injury to the cattle grazing in pastures, where atmosphere is polluted by fluorides.

[9] Accumulation of chloroflouorocarbon (CFC) may cause thining of the atmospheric ozone layer to create the so called **ozone holes**, through which more U-V radiation would come to the earth, leading to overheating of the earth.

[B] Health hazards of air pollution (or direct effects of air pollution on man):

As the air is repeatedly inhaled by us for respiration, pollution of air maximally affects our lungs, and respiration is impaired. Those parts of our body that are exposed to air e.g. skin, eyes, nasal mucous membrane etc. are also affected by air pollution. Moreover, some poisonous components of the polluted air may be absorbed by the blood and they produce various toxic effects. The harmful effects of different pollutants present in air on our body are as follows—

[1] Gases present in smoke (e.g. CO₂, SO₂, nitrogen oxides etc.) irritate the lungs, as a result of which pulmonary diseases like bronchitis, asthma, emphysema etc. may be developed.

[2] CO gas has greater affinity for haemoglobin than that of O_2 . Therefore, if the concentration of CO in the atmosphere is high, it binds with haemoglobin to form carboxyhaemoglobin. This impairs the transport of O_2 and finally leads to hypoxia.

[3] Dust and fibres of different materials inhaled with air produces pneumoconiosis e.g. asbestosis in pipe fitters, black lung disease in coal miners, silicosis in those working with (i.e. inhaling) silica etc.

[4] Benzopyrene (present in smoke) and peroxyacetyl nitrate or PAN (present in smog) are carcinogenic and may cuase lung caner. PAN, ozone and aldehydes present in smog also cause irritation of eyes, skin and respiratory tract.

[5] Heavy metals e.g. Pb, Hg present in air may produce toxicosis and poisoning, leading to neurophysiological and other disorders.

[6] Bacteria and viruses present in air produce infections (air borne diseases) like tuberculosis, influenza, conjunctivitis etc.

[7] Fungal spores, pollens and cotton fibres may cause allergic reactions e.g. asthma, skin erruption etc.

[8] Tobacco smoke inhalation is a predisposing factor for several diseases like emphysema, bronchitis, lung cancer, hypertension, heart diseases, peptic ulcer etc.

- [9] Insecticides and allied chemicals are retained in the body for prolonged periods and derange the activities of nervous system, reproductive system and most other systems of the body.
- [10] The radioactive rays reduce cell division in all tissues and may induce mutation in the germ cells leading to deformities not only in the affected person, but also in the future generations. Radioactivity may even cause extinction of a species.
 - [11] Smog irritates the eyes and produces a sensation of burning pain in the eyes.
 - [12] The U-V rays of sunlight may enhance formation of cataract in the eyes.

Prevention and control of air pollution:

Following measures may be adopted for control of air pollution:

- [1] Restriction of smoke emission: The first and foremost step that should be taken to control air pollution is to prevent the emission of smoke from various sources. For this, two points are to be considered –
- (i) The machines of factories, automobiles, generators *etc.* should be well maintained, so that emission of smoke form them is reduced. In factories, tall chimneys should be used so that the smoke is diluted. To ensure this, laws should be framed and enforced by the government.
- (ii) A proper selection of fuel is to be made; for this, coal and diesel should be replaced by electricity, natural gases, smokeless coal *etc.* as far as possible. The petrol used in vehicles should be unleaded (or lead free).
- [2] Purification of air: Modern techniques should be used to remove pollutants from air; for example:—
- (i) Electrostatic precipitators and cyclonic separators can be used for making the air free from dust and smoke.
- (ii) Filters should be used in factories and machines to absorb poisonous gases from their exhausts.
- (iii) **Scrubber** can be used to remove dusts and gases like NH, and SO₂ from air by spraying water or by passing the air through a dry or wet packing material.
- (iv) Tree plantation should be encouraged in densely populated places, deforestation should be banned and afforestation in barren lands to be done because plants purify the air by absorbing CO₂ and releasing O₂.
- [3] Proper planning of industry and towns: Towns and industry (factories) should be planned and developed at a safe distance from each other, green belts are to be developed between industrial and residential areas.
- [4] Restriction of the use of insecticides: Use of insecticides should be reduced as far as possible and instead of these toxic chemicals, biological methods for pest control (i.e. destruction of fungi, insects etc. by their enemies) should be endeavoured.
- [5] Prohibition of smoking: Smoking habit should be given up. For this, people should be made aware of the injurious effects of smoking with the help of mass media. Legislation could be made to prohibit smoking in public places so that the non-smokers may get rid of the ill effects of smoking; for this 'no smoking zones' are to be made.
- [6] Nuclear explosions: Nuclear explosions and wars should be stopped and care should be taken in handling, storage and disposal of radioactive materials.

Major air pollutants, their sources and adverse effects on human health:

Pollutants	Sources	Adverse effects
Oxides of nitrogen	Automobile exhausts, gas stoves and heaters, wood burning stoves, kerosine, space heaters.	Respiratory tract irritation; bronchial hyperactivity, impaired lung defences etc.
Hydrocarbons	Automobile exhausts, tobacco smoke.	Lung cancer
Carbon monoxide	Automobiles, industries, incinerators and other combustion equipments, tobacco smoke.	Haemoglobin poisoning by producing carboxyhaemoglobin and reduction in O ₂ carrying capacity of blood.
Sulphur di-oxide	Power plants, smelters, oil refineries, kerosine space heaters.	Asthma and chronic obstructive pulmonary diseases, respiratory tract irritation.
Ozone	Automobile exhausts, high altitude air craft cabins, photochemical smog.	
Lead	Automobile exhausts using leaded petrol or gasoline, mining and smelting of lead ores.	
Suspended particles or Aerosols	Power plants, industrial processes and incinerators, vehicular traffic, domestic coal burning etc.	irritations, emphysema, and lung

13.8.4. WATER POLLUTION

Definition: Water pollution is phenomenon by which water is rendered unsuitable for consumption by man and other animals or habitation of aquatic plants and animals due to mixing of any poisonous material or pollutant with it.

Like air, water is also essential for life because all the life precesses require water as the medium. Water is the habitat of many plants and animals that live (respire) by taking O2 dissolved in water. Water pollution has far reaching effects; it causes harm not only to the mankind, but also to most of the animals and plants.

Type of water pollutants and water pollution:

Water pollutants can be classified into three main categories:

[1] Chemical pollutants: This group includes various organic and inorganic chemicals, these chemicals may be-(i) nutrients for growth of plants and microorganisms (e.g. nitrates, phosphates, sulphates), (ii) toxic chemicals (e.g. biocides, acids, alkalies, dyes, petroleum oils), (iii) minerals (e.g. flouride, arsenic) and (iv) heavy metals (e.g. lead, mercury, cadmium).

[2] Physical pollutants e.g. hot water from industries, and radioactive materials

originating from nuclear explosions and other sources.

[3] Biological pollutants e.g. pathogenic micro-organisms (protozoa, bacteria, virus, helminths, algae etc.)

The aforesaid pollutants pollute mainly the surface water (e.g. river, sea, pond, lake etc). However, the underground water of some places may also be polluted particularly by chemical pollutants due to their seepage through soil form various sources.

Water pollution may be classified in two ways

- [1] According to the type of water source being polluted. e.g. surface water pollution and underground water pollution. The surface water pollution may again be of different types such as—river pollution, lake pollution, estuarine pollution, coastal water pollution, open sea pollution etc.
- [2] According to the type of contamination or pollutant e.g. nutrient pollution, metallic pollution, petrochemical pollution, pesticide pollution, thermal pollution, radioactive pollution etc.

Sources of water pollution and nature of pollutants:

Based on their origin, the sources of water pollution are of two broad categories: (i) **Point sources**—These are fixed or localised sources that discharge their effluents at specific sites; for example—sewerage outlet of an area and effluent outlet of a factory. (ii) **Non-point (or dispersed) sources** These are not fixed and consist of large area of undefined location. They include surface runoff from agricultural lands, forests, hills, city roads buildings *etc.* Pollution from point sources can be checked by proper technology, but non-point source pollution is very difficult to control and needs control measures on a large scale. The different sources (or causes) of water pollution and the nature (or type) of pollutant present in them are described below.

[1] Industrial effluents: Generally the factories and industries are situated near the rivers or seas. The industrial effluents (i.e. the waste water of industries) are usually discharged directly (without treatment) into the river or sea water. Such effluents contain a variety of inorganic and organic chemicals that pollute the water body. The industrial wastes such as acids, alkalis, chlorides, phenol, ammonia, nitrates, fluorides, cyanides and heavy metals like lead, mercury, cadmium, chromium etc. are toxic for man and animals.

In many industries including power plants, oil refineries etc., water is used as a coolant for the machinery. Such industries release hot water in the effluent which causes thermal pollution in the water body and endangers the life of aquatic plants and animals.

[2] Sewage: Rivers, lakes, ponds and shallow offshore seas are largely polluted by sewage (i.e. the liquid wastes of drains and municipal sewerage channels) because in many places, untreated or partically treated sewage is discharged into the water bodies. In India, most of the rivers and lakes including the holy river Ganga and the famous Dal lake in Kashmir are heavily polluted by indiscriminate discharge of sewage. Sewage includes the waste waters originating from domestic activities (e.g. bathroom, toilet, kitchen etc.) and small scale home industries.

The pollutants present in sewage are mainly **organic matters** like human and animal excreta and food residues that are bio-degradable. The sewage water also contains some **inorganic pollutants** (e.g. alkalies, sulphates, phosphates, nitrates etc. derived from soaps and detergents) and **pathogens** (disease producing microbes). Most of the biodegradable pollutants (organic matters) of sewage are rapidly decomposed by natural

processes, but when they accumulate in large quantities (i.e. when their input in the environment exceedes the decomposition capacity of the latter), they create problem. The inorganic salts of sewage e.g. nitrates and phosphates are nutrients, which pollute the water bodies by facilitating growth of algae and micro-organisms.

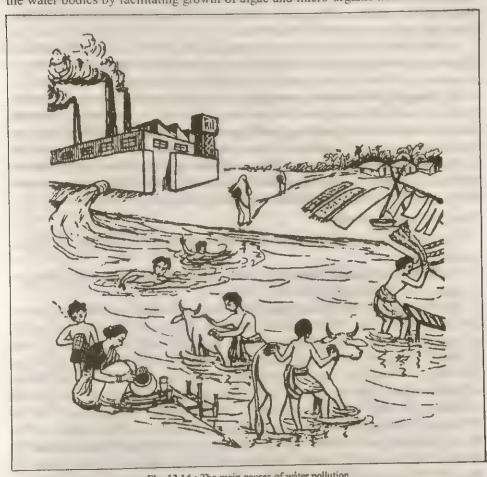


Fig. 13.14: The main causes of water pollution.

[3] Surface runoff from land: The rain water washes away various pollutant materials from land sufface and carries them to water bodies. Pollutants in surface runoff vary according to the nature of land over which it flows. The runoff from agricultural land contains biocides (pesticides, insecticides, herbicides, etc.) and fertilizers (phosphate and nitrate). The runoff from urban and sub-urban areas contains biodegradable organic pollutants, pesticides, petroleum oils and other chemicals, pathogens etc. Industrial areas add chemical pollutants like acids, heavy metals and various other organic and inorganic compounds. In many places, the earth's crust contains large amount of minerals like fluorides, arsenic, lead, copper, iron etc that are also carried in the runoff. The runoff may also contain radioactive materials originating from ashes of atomic explosions falling on the land. All these pollutants present in the runoff heavily contaminate not only the surface water, but also the underground water.

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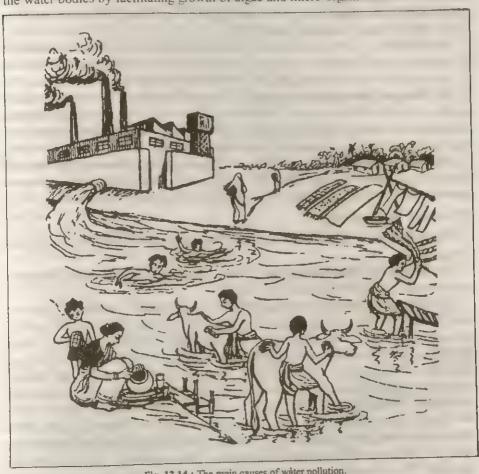


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- [4] Misuse of water bodies: Water bodies like ponds, rivers and lakes are often polluted by their misuse for various human activities e.g. defecation, bathing of man and animals, washing of clothes and utensils etc. Many articles such as dead bodies of man and animals, flowers and other puja offerings, resistance objects like glass or plastic bottles, polythene bags, metal cans etc are often thrown into a river or lake. These materials also pollute the water body.
- [5] Oil spills: Oil spills or accidental discharge of petroleum in oceans, seas, estuaries or ports pollute the aquatic environment. Such oil spills occur from capsized ships or oil tankers, off-shore oil mining and oil exploration activities and oil refineries.
- [6] Dumping of radioctive materials: Radioactive materials are used in nuclear reactors, research laboratories and in the field of medicine. After use, these materials are thrown into seas or rivers. Many such materials have a long half life and thus, they remain radioactive for a considerably long time and pollute the aquatic environment.
- [7] Other sources: The water of lakes and ponds may be polluted by putrefaction of plankton, leaves of trees and bodies of dead animals. Silt accumulation in lakes and rivers reduces their depth and disturb the aquatic ecosystem.

Effects of water pollution:

Water pollution has profound adverse effects on aquatic ecosystem and human beings.

[A] Effects on aquatic ecosystem: Water pollution causes imbalance of aquatic

ecosystem in different ways as detailed below:

- [1] Reduction in dissolved oxygen (DO) content of water: Although oxygen has low solubility in water, the DO content of water bodies is very important for survival of aquatic organisms. The solulubility of O, and thus the quantity of DO in water decreases if any material remains dissolved in water. So, the DO content of polluted water is low. Presence of organic wastes (e.g. sewage, leaves of plants, dead animals etc) and inorganic nutrients (e.g. phosphate and nitrate originating from fertilizers and detergents) in water stimulates the growth of some aerobic bacteria which help to decompose the organic matters. They consume oxygen for decomposition of the biodegradable organic matters, thereby increasing the biological oxygen demand (or BOD i.e. the amount of O, needed by aerobes for biodegradation of organic matters) of the water. This in turn reduces the amount of DO available for other aquatic organisms like plankton, molluscs, fishes etc. in the habitat and may even lead to their death. When the DO content of polluted water body becomes too low, anaerobic bacteria begin to grow rapidly. They decompose the remaining organic wastes anaerobically and produce poisonous gases like hydrogen sulphide (H,S) and methane (CH,) having offensive odour.
- [2] Eutrophication: Pollution of ponds and lakes by agricultural runoff (containing fertilizers) and domestic waste water (containing detergents) increases the the content of inorganic nutrients e.g. nitrates and phosphates in the water bodies. Availability of excess nutrients causes profuse growth of algae i.e. algal bloom. This phenomenon is known as eutrophication. Such algal blooms may totally cover the water surface, release some toxins in water and sometines cause drop in DO content of water. As a result of this, other plants and animals in the water body may die due to toxicity or lack of oxygen. The dead aquatic plants are deposited at the bottom of the water body which is gradually filled up and finally converted to a swampy land.

[3] Ecological imbalance by thermal pollution of water: Thermal pollution or rise of temperature of water bodies due to inflow of hot waste water from industries endangers the life of aquatic animals and plants, and causes ecological imbalance in various ways.

(i) Higher the temperature of water, lower is the solubility of O₂ in it. Thus, thermal pollution decreases the DO content of water bodies, which is unfavourable for survival

of aquatic life.

(ii) Premature hatching of fish-eggs at warmer temperature may increase the mortality of young fishes.

(iii) At higher temperature, many parasites grow at a faster rate affecting the aquatic

plants and animals.

- (iv) Aquatic animals often migrate from thermally polluted regions to other locations.
- [4] Threat to aquatic life by toxic materials: Presence of toxic materials like biocides, heavy metals (Pb, Hg, Cd) etc. may directly kill and eliminate some aquatic organisms, specially the fishes. Certain non-biodegradable toxic chemicals e.g. pesticides undergo biomagnification i.e. they get accumulated in increasing concentrations along the food chain.
- [B] Effects on human beings: Water pollution adversely affects human health and some other human interests.
- [1] Effects on human health: Use of polluted water by human beings may cause various diseases depending upon the nature of pollutants present in it.
- (i) Pathogens: Intake of polluted water containing virus, bacteria and protozoa may cause water borne diseases like cholera, typhoid, jaundice, amoebiasis etc. Bathing

in polluted water may produce infections of skin, eye and ear.

(ii) Toxic chemicals: Water contaminated with surface runoff and industrial effluents may contain various toxic materials like biocides, nitrates, heavy metals (Pb, Hg, Cd), minerals (arsenic, fluoride) and radioactive materials. On intake of such water, these chemicals are absorbed in blood and produce different disorders. Biocides affect more or less all systems of the body; some of these are neurotoxic agents producing disorders of neural functions. Excess nitrate in drinking water is dangerous for human health because it poisons haemoglobin and impairs oxygen transport in the body. Lead present in drinking water (originating from pipes and containers used for supply and storage of water) may produce neural disorders, muscular weakness, anaemia, abdominal pain and constipation. Mercury poisoning (due to consumption of water containing mercury or fishes captured from mercury contaminated water bodies) causes Minamata disease (numbness of lips, limbs and tongue, mental derrangements, loss of hearing and vision etc.) Cadmium pollution produces Itai-Itai disease (a painful disease of bones and joints) and liver and lung cancers. Consumption of arsenic containing underground water for prolonged period produces black foot disease (dark patches on palm and sole and skin lesions) and also causes diarrhoea, neuritis and cancer of skin and lung. Presence of excess fluorides in drinking water (obtained from underground sources) produces a pathological condition known as fluorosis characterised by skeletal and dental deformity and neuromuscular disorders leading to crippling of people. Radioactive material contaminated water causes deformity and dysfunction of various tissues, cancer, leukemia, birth of deformed and abnormal child, miscarriages, impotency etc.

[2] Other effects: (i) Pollution of water due to presence of excess sewage, industrial effluents and resistant ariticles (e.g. plastic or metal or glass containers) as well as algal bloom and oil spillage makes the water bodies and beaches unfit for swimming and other recreational uses. (ii) Death of fishes due to pollution of water bodies affect us economically. (iii) Presence of some toxic materials in water makes the water unsuitable for irrigation.

Prevention and control of water pollution:

Following measures should be taken to get rid of water pollution and its harmful effects.

[1] The industrial effluent should be allowed to enter into river or sea water only after pretreatment and not directly. Big factories should have effluent treatment plant.

- [2] Raw sewage should not be dumped into rivers or oceans and it should be properly treated in sewage treatment plants before being released into the water body. The municipal sewerage system should be modernised and scientific techniques should be employed for treatment of domestic liquid wastes (i.e. removal of organic matters form it). For this purpose, biological processes can be adopted in which the sewage is treated with bacteria to decompose the organic matters present in it before it is allowed to enter a river. The domestic organic solid wastes should be used to make compost instead of throwing them into the sewers.
- [3] Ponds, lakes *etc.* should be well maintained and kept free from planktons, algae and other organic matters. Depth of the streams and their flow should be maintained by occasional dredging operations for silt removal.
- [4] The water reservoirs and rivers from which water is taken for human use should not be used improperly; washing and bathing should not be allowed in such reservoirs. Throwing of garbage, deadbodies, flowers and puja offerings, resistant articles *etc.* into the rivers should be stopped.
- [5] Use of insecticides should be restricted because on entering into our body, these chemicals are retained for a long time and continue to exert toxic effects.
- [6] Radioactive materials, hot water (from factories), oil (from ships) etc. should not be allowed to enter into the rivers and seas. Radioactive materials should be stored in sealed porcelain or glass containers for their decay periods or kept underground or sunk into the sea.
 - [7] The drinking water should be filtered and disinfected by chlorination or boiling.

13.8.5. SOIL POLLUTION:

Definition: Mixing of any substance with the soil that reduces productivity of soil is called soil pollution.

Soil is the uppermost layer of the Earth's surface formed by the weathering of the parent rock. It is the most useful substratum on which plants grow, it is also an useful building material. In the recent years, the soil is getting polluted from domestic, industrial or agricultural sources.

Various soil pollutants and damages caused by them:

[1] Weedicides: Different weedicides like dinitro compounds, MCPA (methyl chloro propionic acid), monuron, 2,4-D (2,4-Dichloro phenoxy acetic acid), and paraquet are used to destroy unwanted weeds in the agricultural fields. They remain in the soil

for long time and destroy different soil borne organisms, imposing problems for the wild life.

- [2] Fungicides: The fungicides may contain heavy metals like copper, arsenic or some are organic compounds like carbendazium, dithane etc. which may cause non-target effect, destroying different friendly organisms.
- [3] Pesticides: The pesticides are mainly of two types— (i) organochlorine compounds like DDT (dichloro diphenyl trichloroethane) and BHC (benzene hexachloride) and (ii) organophosphorus compounds like fonofas, phenyl phosphorothicate. These compounds are converted to different other toxic forms by bacteria. They also cause non-target effect or even enter the food chain and affect the higher consumers like mammals. Very often DDT in trace amount is found in cow's milk, food grains affecting the health of human beings.
- [4] Nematicides: The nematicides like oxamyl and sodium methyl bromide are used to destroy pathogenic soil borne nematodes. But at the sametime, they are harmful to earthworms (Edwards and Lofty, 1972). Thus, the beneficial aspects of earthworm in terms of soil aeration and fertility are extremely reduced. At the sametime, the food resource of certain insects, amphibians and birds are reduced.
- [5] Sewage: It is, common problem in urban areas, it increases the BOD of water bodies and may cause widespread epidemics by contaminating ground water.
- [6] Domestic effluents: In includes mixed solid wastes, vegetable wastes, used batteries, plastics etc., which damages aquatic ecosystem along with ground water.
- [7] Industrial effluents: They cause widespread pollution of the soil in urban and semi-urban areas and include heavy metals, acids, alkalis, persistent organic pollutants, plastics, specific chemicals and dyes *etc*. They damage the drainage system, change the soil pH, destroy the soil based ecosystem, cause biological magnification.

Prevention and control of soil pollution:

- [1] The use of pesticide, fungicide or nematicide is to be reduced.
- [2] There should be more reliance on biological, physical or cultural control of pests.
- [3] Different micro-organisms should be grown in soil, which can reduce the toxic pollutants of the soil.
- [4] Water recycling should be done in efficient treatment plants, so that epidemics through contamination of ground water can be averted.
- [5] Industrial effluents should not be released in to the agricultural fields without proper treatment.

13.8.6. NOISE POLLUTION

Definition: Increase of noise i.e. unwanted and loud sound which is displeasing to the ear, in the surroundings is called noise pollution or sound pollution.

Sound has several characteristics such as pitch, timber and intensity. Among these, the intensity or loudness which depends on the amplitude of the sound wave, is mainly responsible for noise pollution. The intensity of a sound is expressed (or measured) in

decibel (dB) units (i.e. one tenth of bel unit). The intensity levels of a few common sounds are as follows: minimum audible sound — O dB; whispering — 20-40 dB; normal conversation — 60 dB; heavy traffic — 80 dB; lound speaker and railway station — 90 dB; noise in subways — 100 dB; thundering — 120 dB; sound of jet planes and sirens — 160 dB etc. A sound with an intensity 80 dB or more is known as noise and causes pollution. Sound intensity of 120 dB is highly irritating and displeasing; above 140 dB, it becomes unbearable.

Sources or causes of noise pollution:

The major sources or causative factors of noise pollution are the following:

- [1] Industrial noise: Machines of factories and workshops, while in operation, emit characteristic high intensity sounds originating from friction or collision between materials. This type of industrial noise affects mainly those people, who work in the factories or dwell nearby.
- [2] Noise from vehicles: The engines of vehicles such as motor cycles, cars, buses, trucks, trains, aircrafts etc. produce noise while running. In addition, trains and tramcars produce a continuous sound due to friction between the wheels and the rails. The horn of vehicles, particularly the electric horn or air horn is a major cause of noise pollution in areas having heavy traffic. Thus, the magnitude of noise pollution is higher in railway stations, airports and streets with heavy traffic. Naturally, persons living near or working in these places as well as the drivers are the victims of this type of noise pollution.



Fig. 13.15: The chief sources of noise pollution.

- [3] Noise from ceremonies and festivals: Noise originating from amplifiers, loud speakers, band parties, fire works and crackers also cause pollution.
- [4] Domestic noise: With the advancement of technology, the use of household appliances such as generators, water pumps, radios, televisions, grinders and mixers is increasing day by day and it is also raising the level of noise pollution.

[5] Noise in congested and busy areas: Business centres and highly congested areas of the cities e.g. bazars, share markets, subways, fairs etc. are polluted by talking and shouting of many people at a time.

The urban areas are by nature more noisy because of the sound produced from various sources as mentioned above. Moreover, the sound once generated is repeatedly reverberated by the multistoried buildings and is dissipated very slowly. This is why the level of noise pollution is much greater in the towns and cities.

Harmful effects or hazards of noise pollution:

Noise pollution affects the human beings in several ways as described below:

[1] Hearing impairments: Over-exposure to noise affects the auditory apparatus and causes hearing loss, which in turn creates various problems. Noise has a masking effect on ordinary sound intensities. For this reason, it becomes difficult to hear normal conversations in noisy places e.g. running trains, subways, share markets etc. and one has to talk loudly, which evokes irritation.

People who work in factories or workwhops amidst noisy machines, gradually become **partially deaf** and they can hear louder sounds only. Similarly, those dwelling near busy airports, railway stations or roads show the signs of early **presbycusis** (loss of hearing due to aging). A sudden and very loud sound *e.g.* explosion or thundering may lead to a temporary loss of hearing.

- [2] Mental upset: Man and animals exhibit a shock like state called startle reaction due to a sudden intense sound. This is often accompanied by nervousness, annoyance, nervous breakdown. Exposure do continuous noise causes mental irritation.
- [3] Visceral reactions: A continuous noise produces various visceral abnormalities such as palpitation or tachycardia (increased heart rate), hypertension (increased blood pressure), vertigo (dizziness), nausea, vomiting, insomnia, loss of appetite etc.
- [4] Metabolic defects: Continuous exposure to noise may also cause metabolic defects such as diabetes mellitus (hyperglycemia) due to endocrine disorders.
- [5] Ecological disturbance and economic losses: Noise pollution affects not only the human beings but also other animals and insects. Birds and insects migrate from the places of high noise pollution level. As a result of this, pollination and thereby agriculture is hampered which indirectly causes economic loss to man. Walls and buildings develop cracks under the stress of explosive sound and intense vibration.

Prevention and control of noise pollution:

Methods used to control noise hazards can be grouped into three categories as described below:

- [1] Control of noise production: The point to be considered first, when control of noise pollution is sought, is restriction of noise production *i.e.* control of noise at source. To achieve this, following steps should be taken –
- (i) Noisy machines should be replaced by noiseless ones. Machines should be well maintained and lubricated to reduce the frictional noise.

- (ii) When machines cannot be changed, silencers should be used (particularly in automobiles).
 - (iii) Electric horns and air horns are to be prohibited.

(iv) Random use of loudspeakers, amplifiers etc. are also to be stopped.

- (v) Factories and workshops (press, lathe etc.) should not be established in residential areas. Residing very close to busy railway stations or airports is to be discouraged.
- [2] Control of noise radiation: When the amount of sound emitted from its source cannot be further reduced, the next step to be taken is to restrict it from being radiated or to absorb it so that the sound is quickly dissipated. For this, the following measures can be adopted.

(i) The noisy machines should be confined within sound proof chambers made up of fibre glass, concrete etc., so that the noise emitted by them may not pollute the

environment.

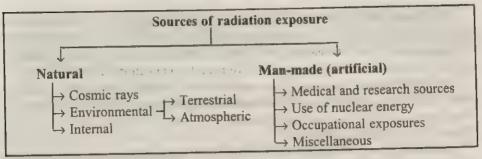
- (ii) Walls and ceilings of noisy rooms and auditoriums could be made with such materials that absorb sound and prevent reflection of noise. For this, hollow bricks can be used in walls and 'acoustic' tiles can be used in ceilings. Walls should be unevenly plastered so as to make them rough surfaced for preventing reflection of sound.
- (iii) Trees are good sound absorbers; so, trees should be planted around the factories, air ports etc. and on the two sides of the busy roads.
- [3] Personal protection: When the above methods are of little value, as in the case of a person who works in close vicinity to the noise source (e.g. operator of a noisy machine), personal protection is the only way to get rid of the noise pollution. This is accomplished by the use of ear plugs or ear muffs, which prevent the entry of sound into the ear. The term ear plug is used for any kind of material that is inserted into the external auditory canal whereas ear muff is a device applied to cover the external pinna.

13.8.7. RADIOACTIVE POLLUTION: RADIATION HAZARDS

The atoms of radioactiove elements have unstable nuclei (i.e. an unstable combination of protons and neutrons in their nuclei) which undergo spontaneous disintegration (called radioactive decay) to form new atoms, with emission of three kinds of radioactive rays (or radiations)- α-rays, β- and γ-rays. The phenomenon of spontaneous emission of radiations form disintegration of radioactive materials is called radioactivity. The α-, β- and γ-rays interact with matter to ionize its atoms by ejecting orbital electrons; so, they are called ionizing radiations. X-rays and cosmic rays also have the ionizing effect and are included in ionizing radiations. Ionizing radiations are present in all the life supporting components of environment like air, water and soil, and they adversely affect the biotic community; so, they are considered as pollutants. Thus radioactive pollution refers to the physical pollution of environment (air, water and soil) by ionizing radiations.

Sources of radiation exposure:

The sources of radiation to which man is exposed may be natural or man-made. Exposure to low levels of natural radiations may not be fatal. But with the advancement of science, the chances of exposure to man-made sources of radiations have increased, which may be dangerous. Various sources of ionizing radiations are discussed below.



[1] Natural sources:

(i) Cosmic radiation: Cosmic rays, which originate in outer space are weakened while passing through the atmosphere before they reach the earth's surface. But the impact of cosmic radiations are important for commercial jet pilots and astronauts.

(ii) Environemental sources: Natural radiations are present in man's terrestrial

and atmospheric environment.

(a) Terrestrial radiation: Radioactive elements like uranium, radium, thorium and the isotope of potassium (K40) are present in soil, rocks and buildings.

(b) Atmospheric radiation: The atmosphere contains small quantities of radioactive

gases like radon and thoron.

(iii) Internal radiation: Man is subjected to internal radiation from the radioactive matters like uranium, thorium and radioisotopes of potassium (K₄₀), carbon (C₁₄), strontium (Sr₉₀) etc. present in body tissues in traces.

[2] Man-made or artificial sources:

(i) Medical and research sources: Radiations and radioisotopes are used for medical (diagnostic and therapeutic) and research purposes. Diagnostic use of medical and dental X-rays is the greatest man-made source of radiation exposure to human beings now a days. By this, the patients as well as the radiologist and medical technicians are exposed to radiation. Radiotherapy for cancer patients is another source of radiation exposure. Radioisotopic materials are used for diagnostic (hormone assays etc.) and research (tracer techniques) purposes. Waste water containing these radioactive substances may pollute the rivers and lakes.

(ii) Use of nuclear energy: Nuclear (atomic) energy is used in nuclear weapons and nuclear reactors. Nuclear weapons (e.g. atom bombs) are used in wars and also for testing the nuclear power of a country. Such nuclear explosions release some radioactive substances like isotopes of carbon (C14), iodine (I131), cesium (Cs137) and strontium (Sr₉₀) into the atmosphere. These radioactive particles are blown away by air currents and get distributed in wide areas. They float down to earth or are carried down to earth by rain drops. Thus, soil and water get polluted by radioactive substances. From the soil, they enter into the food chain affecting different forms of life including

man.

In nuclear reactors (power plants), isotopes of uranium (U235) etc. are used for generation of electricity. Normally, the nuclear power plants do not cause air pollution. But the nuclear reactor wastes contain highly radioactive substances that may pollute the environment, if not handled with care. Moreover, accidents is nuclear power plants (example-Three Mile Island of USA in 1979 and Chernobyl of USSR in 1986) also cause tremendous pollution of air, soil and water due to leakage of radioactive substances into the atmosphere.

(iii) Occupational exposure: Persons who are engaged in (a) diagnostic and research laboratories using X-rays and radioisotopes, (b) production of radioisotopes, (c) mining and refining of plutonium and thorium, (d) nuclear reactors and (e) production and test of nuclear weapons are specially vulnerable to radiation exposure.

(iv) Miscellaneous sources: Some appliances of everyday use such as luminous dials and markers, television sets, and similar gadgets are radioactive. But radiation

from these sources is too small to be harmful.

Effects of radioactive pollution:

Gamma-rays and X-rays are more effective on human body because they have much higher power of penetration through tissues. Radioisotopes with longer half-life (i.e. time taken for disintegration of half of the atoms in a given mass) produce greater damage because they remain radioactive for longer periods. The extent of tissue damage depends on the amount (dose and duration) of radiation exposure. Nuclear explosions and nuclear reactor accidents are most dangerous because they produce very high degree of radiation.

Ionizing radiations cause conformational charge in biomolecules (e.g. proteins, enzymes, nucleic acids etc.) leading to the loss of their biological activity. The most dangerous effect of radiation is the damage of **chromosomal DNA**, which may cause failure of **mitotic cell division** and even **mutations**. Due to failure of mitosis, the tissues needing high proliferation rate (e.g. hemopoietic tissue of bone marrow, lymphopoietic cells of lymph nodes, intestinal mucosal cells, gametogenic cells, germinative cells of skin etc.) are most affected leading to their structural and functional abnormalities. Radiation therapy given to cancer patients helps to check the uncontrolled proliferation of cancer cells, but at the same time, may damage the normal tissues. Chromosomal mutations caused by radiation may lead to structural deformities, cancer or genetic defects that may be expressed much later and even in future generations.

The short-term (i.e. immediate) effects of radiation include - [1] Nausea, vomiting and diarrhoea; [2] Damage of bone narrow, decreased blood cell (RBC, WBC and platelet) counts and blood level of antibodies (i.e. low immunity); [3] Ulcers and haemorrhage in skin, GI tract and other tissues, with secondary infections and loss of hair; [4] Neural disorders like drowsiness, convulsions and coma; and [5] Death due to above reasons.

The long-term (i.e. delayed) effect of radiation are—[1] Cataract; [2] Sterility; [3] Abnormalites in foetal development and abortion; [4] Leukemia; [5] Cancer and [6] Genetic mutations affecting the progeny.

Control of radioctive pollution:

There is no cure of radiation damage. So, every precaution must be taken to prevent radioactive pollution. These are –

[1] Nuclear weapons should be banned.

[2] Leakage of radioactive materials from nuclear reactors and power plants, careless handling, transport and use of radioactive substances are to be stopped. Safety measures against accidental leakage should be taken in power plants.

[3] The waste materials of nuclear reactors and power plants should be disposed off

very safely.

[4] Regular monitoring through frequent sampling and analysis is necessary in high risk areas.

[5] Effective protective measures should be taken by the workers occupationally exposed to radiation. For this, they should use lead shields or lead rubber approns.

[6] Unnecessary X-ray examinations should be avoided especially in case of children and pregnant women.

13.8.8. BIOMAGNIFICATION:

Biomagnification simply denotes enhancement in the concentration of a particular substance along the food chain.

By this method, a toxic substance enters the food chain at a very low concentration and as it moves up into the consumers of the higher trophic level, its concentration increases, which might induce lethality to these animals. This phenomenon can operate both in terrestrial as well as aquatic ecosystems. Barker in 1958 showed that the concentration of DDT in the soil below elm trees is 10 ppm, the earthworm contained 86 ppm of DDT. The Robin bird died after consuming 11-12 such earthworms and the liver of the dead bird showed 744 ppm of DDT, while their brain showed 250 ppm of DDT.

Woodwell (1967) have showed 0.002 ppm of DDT in the body of zooplanktons, it increased to 2.07 ppm in the body of needle fishes and 75.5 ppm in the body of fish eating gulls. Thus, the adverse effect of DDT is felt in the body of higher consumers by the phenomenon of biomagnification.

Similar biomagnification can be observeed in case of heavy metals like mercury causing Minamata disease, lead causing anaemia in mammals.

13.8.9. BIOACCUMULATION:

The phenomenon of accumulation of toxic substances in the body of living organism is known as bioaccumulation.

This phenomenon depends on the rate of uptake, duration of exposure, rate of elimination, lipophilicity or solubility in fat molecules. In general, plants have better capability of bioaccumulation, they accumulate these substances along with excretory matter in the cell wall, bark, fruit coat, leaves etc. Sometimes they produce some proteins, that bind with toxic heavy metals and are called phytochelatins. Heavy metals are also accumulated in the plant body of cryptogram like algae and fungi. Purkayastha and Mitra (1994) had shown accumulation of heavy metals in the fruit bodies of edible mushrooms, which can induce toxicity to mammalian sytem. Some plants accumulating a particular heavy metal at high concentration may serve as bio-indicator for that heavy metal pollution. Mitra (1998) has shown that roadside grasses growing along the highways in U.K. may serve as bio-indicator for lead pollution. Animal systems can also accumulate toxic heavy metals with the help of metal binding proteins called metallothioneins. Soluble insectisides may accumulate in the fatty tissues of vertebrate animals (Murty 1986). But the phenomenon of bioaccumulation is less probable in animals than in plants.

13.8.10. DISORDERS IN MAN CAUSED BY HIGH CONCENTRATION OF **HEAVY METALS:**

[1] Lead: 11 : 15 ... The primary source of lead is mostly the soluble form like sulphide. About 15% of the ingested lead is absorbed through small intestine, of which 90% of lead goes to blood and later it is deposited in liver, kidney, bones and nerves. It causes the following disorders:

(i) It causes **osteolysis** (degradation of bone), painful conditions in the joints, movements are impaired. It can impair muscle activity and reduce the uric acid excretion causing gouty condition. The disease is termed as **dislexia**.

(ii) It blocks the biosynthesis of haemoglobin by inactivating the enzyme δ amino

levulinic acid dehydratase, as a result of which anaemia is caused.

(iii) It causes degenerative changes in the motor nerves, ganglia and affects mental agility.

(iv) It damages the kidney, causing renal fibrosis, glomerular schlerosis.

(v) It can cause damage to testis and ovary impairing the process of gamete formation in both male and female.

(vi) It can move into the body of the foetus through the placenta, causing inborn developmental anomalies in children.

[2] Cadmium:

Cadmium exposure primarily occurs from nickel-cadmium battery plants, paints, dyes etc. About 15-20% of cadmium enters the human body through respiratory tract, about 5% enters through the gastro-intestinal tract. After entering blood, it is primarily deposited in the liver and kidney, it acts as a potent enzyme inhibitor, blocking various metabolic activities. The toxic implications of cadmium are as follows:

- (1) A specific disease called **Itai Itai** occurs due to cadmium ingestion, which was observed in Toyama, Japan by **Nogawa**, 1978. This cadmium came from the nearby mining complex and it contaminated the paddy fields. The initial symptoms include back pain, muscular rheumatism followed by softening of bones or osteomalacia, decrease in body weight, proteinuria, glaucoma of the eye and ultimately death. It occurs in those cases, where the average intake of cadmium is 600 μg/day.
- (ii) It also causes obstructive lung diseases like chronic bronchitis, progressive fibrosis of the lung leading to emphysema.
- (iii) Immunological disorder, cardiovascular diseases and hypertension may also result from low cadmium exposure.
- (iv) Renal damage include degeneration of renal tubules, progressive interstitial inflammation and fibrosis.

[3] Mercury:

The primary source of mercury is its mineral, **cinnabar** coming from various industries like plastic, electrical or even from smelters. Mercury primarily exists in 3 forms, elemental mercury, inorganic mercury and organic mercury. The last one is more toxic than the first two forms. Under anaerobic condition, a bacterium *Clostridium cochlearum* transforms mercury to toxic methyl mercury, while *Pseudomonas* can do the samething in aerobic condition. Sometimes under alkaline condition, mono-methyl mercury is converted to volatile dimethyl mercury, that contaminate the atmosphere, organomercurial compound are absorbed at a very high rate through tht G. I. tract. The various toxic implications of mercury ingestion are as follows:

(i) The Minamata Bay in Japan got contaminated with inorganic mercury released from a mercury smelter in 1952, which was readily converted to methyl mercury and the fishes showed a ready uptake of 10-12 mg of mercury per kg body weight. The people consuming these contaminated fishes showed neuro-motor disturbances, mental disorder, congenital abnormalities and cerebral palsy. Over 100 people were affected and 46 died; the disease is called Minamata disease. Later, with the increase in infected people, the mercury smelter was closed down.

- (ii) Mercury binds with sulphydryl groups and mactivates several sulphydryl enzymes, impairing the metabolic activities.
 - (iii) Mercury vapour may cause acute bronchitis or interstitial pneumonia.

(iv) It can also cause gastro-intestinal damage, blood tinged diarrhoea, abdominal cramps.

(v) The central nervous system is severely affected, the neurones undergo necrosis and degenerative changes in the neurones of cerebral cortex causing loss of hearing, impairment of vision, paralysis, loss of speech or coma.

13.9. Green House Effect and Ozone Hole

The green house is a place where temperate plants are kept at elevated temperature in a glass house. The entire earth is surrounded by a blanket of gases, which allows the entry of sun's ultraviolet and infrared waves and after being reflected from earth's surface, they are radiated back to outer atmosphere. This radiation is restricted by the atmospheric gases, as a result of which the earth's temperature is warm and hospitable. In this way, the earth acts like a green house and the plants and animals are protected from extreme coldness. But the presence of different green house gases like carbon dioxide, methane, nitrous oxide emitted from industrial pollution absorb these infrared and heat waves causing global warming and this is how green house effect becomes acute. Moreover, the depletion of ozone layer in the stratosphere has also added to this problem.

13.9.1. OZONE LAYER AND ITS DEPLETION:

The ozone layer is about 15-40 km above the earth's surface and 90% of ozone is present in the stratosphere. The formation of ozone from molecular oxygen takes place spontaneously utilizing the radiations of 2200-2900 Å. The depletion is also natural and it maintains a stable equilibrium with the rate of formation

$$O_2 \rightarrow [O] + [O]; O_2 + [O] \xrightarrow{h\gamma} O_3$$

The O₃ layer gets depleted in presence of various industrial pollutants. It was detected for the first time by the U. S. chemist H. Johnson in 1971. Later Farmer and his co-workers in 1985 showed that nearly 40% of ozone has been depleted above the south pole.

Causes of ozone depletion:

(i) Nitric oxide: It is obtained from the excessive use of nitrogenous fertilizers and the burning of the fuel of supersonic jet liners.

The depletion occurs in the following way:

$$\begin{array}{c} NO + O_3 \rightarrow NO_2 + O_2 \\ NO_2 + [O] \rightarrow NO + O_2 \end{array}$$

Nitric oxide reacts with O3 to produce nitrogen dioxide, which again reacts with nascent oxygen to produce nitric oxide again with molecular oxygen.

(ii) Hydroxyl ions: The hydroxyl ions are produced by photo dissociation of water molecules in the stratosphere. It reacts with O3 to produce HO2 (super oxide), which reacts with another molecule of O3 to produce OH and molecular oxygen.

$$OH + O_3 \rightarrow HO_2 + O_2$$

$$HO_2 + O_3 \rightarrow OH + 2O_2$$

(iii) Chlorine atoms: These chlorine atoms are produced from compounds called chloro fluoro carbons (CFCs), these are used in refrigerators and cosmetic sprays and belonging to twelve different classes. They are colourless, odourless compounds, that liberate nascent chlorine in the stratosphere which breaks O, and convert it to chlorine monoxide. The chlorine monoxide again reacts with nascent oxygen to produce chlorine atoms in the form of chain reaction.

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + [O] \rightarrow Cl + O_2$$

Effect of ozone depletion:

The various consequences of the stratospheric ozone depletion are as follows:

(i) Entry of harmful solar waves: The entry of UV-B and UV-C solar waves (below 3000 Å) causing massive damage to terrestrial life and that of the shallow aquatic areas. They cause widespread formation of thymine dimar, which is beyond any correction and ultimately results in skin cancer. At the sometime, the infra-red waves and heat waves also enter the lower atmosphere causing global warming.

(ii) Eye damage: Greater UV exposure is directly proportional to cataract formation.

It also damages the pigment of the retina.

(iii) Destruction of ecosystem: The different ecosystems belonging to land and water are severely damaged, marine ecosystems may collapse completely due to destruction of the planktonic species.

(iv) Loss in primary productivity: The plants will show depletion of chloropyll, also called solarization, as a result of which the primary productivity is reduced

substantially.

(v) Melting of polar snow: The ice capped peaks and the polar snow melts, as a result of which, the water level in the seas and oceans will rise, all the low-lying areas,

including the major parts will be under water.

(vi) Photochemical Smog: The incidence of photochemical smog will increase considerably, as a result of which the photosynthetic productivity is reduced substantially. Incidence of respiratory diseases also increase greatly, particularly in young children and in aged people.

13.9.2. ACID RAIN

The term acid rain means precipitation of acid in the form rain water with extremely low pH. It occurs due to accumulation of oxides of nitrogen and sulphur along with aerosols. Actually these oxides get dissolved is condensed water vapour on the aerosol surface and come down as acid rain. The hydrochloric acid liberated from the oxidation of organochlorine compounds also gets dissolved in this water vapour.

$$H_2O + \xrightarrow{+SO_2} H_2SO_3 \xrightarrow{+[O]} H_2SO_4$$

 $2NO \xrightarrow{+O_2} 2NO_2 \xrightarrow{+H_2O+[O]} 2HNO_3$

Thus, acid rain contains sulphuric acid, nitric acid, sulphates, nitrates and hydrochloric acid. Its pH is 2.5 to 4.8 and the various damages caused by acid rain are as follows:

(i) It damages buildings, monuments (like Tajmahal).

(ii) It lowers the pH of the soil, as a result of which, the friendly microbes are destroyed.

(iii) The leaf surfaces are destroyed and so the photosynthetic productivity is extremely reduced.

(iv) The fabrics, textiles and paintings may be severely damaged by acid vapour.

(v) It can be extremely harmful to human beings causing damage of the skin and mucus layer of the respiratory tract.

(vi) The alkalinity of water bodies is reduced remarkably, the microbial activity is

reduced and the chemical property is modified.

Control: (i) The acid rain can be effectively controlled by controlling industrial emission. The acid vapours instead of being liberated, are to be solubilized and recycled.

(ii) The control of vehicular pollution will effectively reduce the emission of NO_x and SO₂ and thereby acid rain can be controlled.

Natural emission from volcanic erruption cannot be controlled, so in that case,

urgent evacuation is necessary.

13.9.3. BOD and COD:

BOD or Biochemical/Biological oxygen demand is the amount of oxygen required by micro-organisms to decompose organic matter present in water kept at 25°C for five days in an incubator. BOD is not a pollutant, it is a measure of the effect of certain types of pollutants; so, high BOD means high concentration of nutrients, i.e. a condition similar to eutrophication. BOD is an indicator of water pollution, it is particularly important for sewage treatment. High BOD in the water body makes it difficult for aquatic organisms to survive, it is reduced by increasing dissolved oxygen (DO) in the water body.

COD or Chemical oxygen demand is actually the oxygen required in a water

body to convert organic waste to inorganic waste.

It increases due to industrial pollution and like BOD, it also reduces the DO level of water. If it goes down below 3 ppm, the breathing of aquatic organisms is hampered. The COD level is controlled by adequate oxygenation of organic waste.

13.9.4. THERMAL POLLUTION

Definition: The increase in the temperature of an ecosystem due to industrial or mixed sewage pollution is known as thermal pollution.

Sources of yhermal pollution:

The various sources of thermal pollution are as follows:

(i) Thermal or nuclear power plants: It is the major source of thermal pollution in the aquatic bodies. About 70% of the heat discharged in power plants comes out as waste heat and in this country, it becomes a major problem because thermal power plants are the most popular form of power generation.

(ii) Industrial source: This can either be in the form of industrial effluent or in the form of water generated from the cooling towers. In the first case, the effluent generated is at higher temperature, while in the second case the water remains at an elevated

temperature.

(iii) Sewage effluents: The sewage effluents remain at a temperature 4°C-8°C above the water temperature and this may cause moderate thermal pollution.

Damages caused by thermal pollution:

(i) The water at higher temperature is detrimental to the planktons, invertebrates and smaller aquatic organisms.

(ii) The mechanical impingement present on the side wall of cooling tower pipes

may kill small fishes.

(iii) Chemicals added to remove the slime within the cooling tower may cause death of aquatic organisms.

(iv) The higher temperature may cause melting of cellular fat, coagulation of protein and inactivation of enzymes in fishes.

(v) The temperature above 35°C in water body may kill several small and large

fishes together.

- (vi) The reproductive processes may be triggered at elevated temperature, which will lead to deposition of eggs in prematured state, as a result of which external fertilization fails.
- (vii) Gas bubbles are formed within the water body because normally at lower temperature, the water is saturated with oxygen and they come out as bubbles with the increase in temperature. These bubbles enter the gills and chokes the fish to death, the disease is called **gas bubble disease**.

(viii) The ecological impact of heated water reduces the gaseous exchange with the water surface, as a result of which the gaseous content of the water body is reduced.

Control of thermal pollution:

- (i) The temperature of the water is reduced, before it is discharged outside.
- (ii) The heated water is discharged into a system of cascades for rapid cooling.
- (iii) The heated effluents are stored in larger tanks instead of being discharged into adjacent water bodies.

13.9.5. TOXICOLOGY OF INDUSTRIAL WASTES.

The pollutants produced from various industries and their chemical characteristics vary and naturally their damages and disposal also vary from each other. Some of these pollutants, their characteristics, damages induced and disposal devices are discussed in the following table:

Pollutant Source	Broad Characteristics	Damages Induced	Disposal device
1. Textile industries	Alkaline effluent, high B.O.D, suspended solid.	Water bodies are damaged, respiratory (C.O.P.D) disorders.	Neutralization, trickling filtration, aeration, chemical precipitation.
2. Leather industries	Precipitated lime, sulphides, chromium compounds, hard solids.	minute profitations and	Sedimentation and bio- logical treatment.
3. Dairy farms	Soluble organic matter, including protein, lipid and lactose.	Increases the COD/BOD level of water bodies.	Activated sludge treatment and biological treatment.
4. Brewaries and distillaries :	Organic compounds with high nitrogen, various fermented products.	Persistant organic pollution of water body.	Recovery, concentration, centrifugation, evaporation and trickling filtration.
5. Pharmaceutical industries :	Suspended and dissolved organic matter including vitamins.	Non-target toxicity by residual products.	Evaporation of volatile matter, drying and precipitation.
6. Food processing industries:	Foul odoured, suspended, semi-decomposed solid, high BOD and high pH.		Screening, settling, trickling filtration, disposal into sea.
7. Bakery units :	Sugar, flour, detergents.	Increeases BOD, forms a scum on water body.	Biological oxidation.
8. Paper pulp industry	Suspended, colloidal particles, dissolved solids, high pH solutions.	Changes the pH of aquatic bodies.	Settling, lagooning, aeration, biological treatment.
9. Photographic industries :	Alkaline in nature, mixture of different organic and inorganic compounds.	Heavy metal toxicity, drift in pH.	Metallic silver is recovered and the wastes are discharged into municipal sewer.

Pollutant Source	Broad Characteristics	Damages Induced	Disposal device
	Phenolics, sulphur compounds	Acid rain, increase in per- sistent organic pollutants.	Prevention of oil spill, recovery and acidification, burning of alkaline sludge, removal by floatation.
11. Detergent manufacturing units.	Saponified solutions with high BOD	Formation of froth, reduction in dissolved oxygen.	Floatation, skimming and precipitation with CaCl ₂ .
12. Glass	Red coloured, alkaline, suspended solids.	Larger and smaller fishes are killed, pH increases.	Calcium chloride precipitation.
13. Rubber industries :	Impurities like latex, rubber particles, chloride, variable pH effluents.	Lowering of pH of water bodies, choking of water ways.	Aeration, chlorination, sulfonation
14. Acid plants	Dilute acids, effluents with low pH, organic components.	Acid rain, lowering of pH, damages the mucus.	Burning of organic matter, neutralization
15. Explosives :	T N.T, acidic compounds, organic acids, alcohols, cotton dust, heavy metal, oils and lipids.	Accidental explosions, frothing, respiratory distress.	neutralisation, adsorption, floatation and precipitation.
16. Pesticide plants:	Benzene, chlorine and phosphate derivatives, toxic pesticidal by-products.		chlorination, dilution and storage
17. Plastic industries :	Polymeric compounds, organic acids, phenols and formaldehyde.	Increase in COD polyphenol toxicity destruction of friendly microbes.	recycling.
18. Radioactive materials :	Waste from research laboratories, discharge from nuclear power plants radioactive compound.	including cancer of various, organs.	certain cases.
19, Coke manu- facturing units.		the water body, destruction of aerobic organisms.	components, bio
20. Paint manufacturing units	Synthetic resin, solven pigments, heavy metals lil lead, chromium etc.	Increase of BOD deposition of heavy metals in the microbes and sub-seque bio-magnification.	he and pigments, precipitation

13.9.6. WETLAND AS NATURE'S KIDNEY

Wetlands are areas inundated or saturated by surface or ground water.

The tropical wetlands cover a total area of 2.64 million sq. km., while the temperate wetlands cover an area of 5.72 million sq. km.

The wetlands can be classified into 4 major types as per Dugan (1990)

- (i) Marine: It includes the rocky marine shores and shallow shores of the sea.
- (ii) Estuarine: It includes the broad river mouth at the interface of river and sea.
- (iii) Lagoons: Saline lakes having connection with the sea.
- (iv) Salt lakes: Permanent salty or alkaline lakes, flats and marshes.

Importance of wetlands:

(i) They help in recharging of groundwater, that is the water goes back into the underground sandstone or rocky aquifer. It also acts as a filter of certain waste and contaminants. It controls water run off and replenishes water level is the surrounding areas by discharging the stored water, there by agricultural productivity is controlled and eutrophication is prevented.

Apart from that, the various biological, chemical and physical processes of wetlands transform and immobilize wide range of environmental contaminants and nutrients, heavy metals are rendered ineffective. For this reason, wetlands are referred to as **kidney** of the nature.

- (ii) It helps in the **control of flood** by absorbing excess water and releasing the rain water slowly.
- (iii) It has a **binding effect** with respect to soil erosion, unusual rise in water level in rivers and seas.
- (iv) Regular depositon of nutrient enriched silt makes the soil fertile and thereby agricultural productivity is maintained.
 - (v) It act as a sink by depositing excess of nutrients and contaminants.

Loss of Wetland:

The loss of wetland is a serious problem and it includes 30 different wetlands of India. The major causes of this loss are:

- (i) Injudicious aqua-culture.
- (ii) Construction of dams.
- (iii) Construction of houses, roadways.
- (iv) Excessive extraction of ground water, oil and natural gas.
- (v) Disposal of uncontrolled solid wastes.

Prevention of wetland loss:

The wetlands are controlled in the following ways:

- (i) Development of catchment area.
- (ii) Control of siltation and pollution.
- (iii) Stringent laws to protect wetland.
- (iv) Demolition of unauthorized constructions and prevention of land filling.
- (v) Adequate public awareness for wetland protection by involving NGO, local bodies, clubs and community at large.
- (vi) Environment impact assessment should be carried out before modifying the existing wetlands.

13.10. Major Environment Protection Laws in India

The environment protection laws was initiated in India in 1878 and the last law was stroduced in 2000.

These laws are cited in the table below:

Year	Name of the Act	Remark
1878 1879 1887 1905	Indian Forest Act. Elephant Preservation Act. Wild Bird protection Act. West Bengal Smoke Nuisance Act. Wild Birds and Animal Protection Act.	The first protection act for conserving flora. The first act to preserve wild animals. The act to protect wild animals. The law preventing the nuisance arising from smoke in the urban areas, the act was amended in 1978. Protection of wild birds and animals.

Year	Name of the Act	Remark
1932	Bengal Rhinoceros Preserva-	The act to protect the one horned Rhino in
	tion	West Bengal. The most powerful act after independence to
1972	Wild life Protection Act.	protect wild animals.
1974	Water (Prevention and Control	The prevention of water pollution
17/4	of Pollution) Act.	The prevention of the property
1977.		It was directed against the prevention of water
	of Pollution) loss Act.	loss.
1980	Forest Conservation Act.	The law for the conservation of reserve forest
		was strengthened.
1981	Air (Prevention and Control	The first proper air pollution control act.
	of Pollution) Act.	
1986	Amendment to Wild life	The first amendment of the wild life protec-
	Protection Act.	tion act of 1972.
1986	Environment Protection Act	The first comprehensive act aimed at conser-
	(E.P.A.)	vation and protection of environment.
1988	Modification of Forest conser-	The injudicious felling of tall trees were
	vation Act.	prevented. The management rules for hazardous waste
1989	Hazardous wastes (manage-	was incorporated under the E.P.A of 1986.
	ment and handling) Rules under E.P.A. 1986.	was incorporated under the 251 11 of 1700.
1991	Amendment to Wild life	The amendments included addition of plants,
1991	Protection Act of 1972	wetlands were designated, boundaries of
	Total of 17	sanctuaries were specified.
1991	Notification of Coastal	The coastal areas were notified and protection
1//1	Regulation zone.	was ensured under EPA, 1986.
1993	West Bengal Fisheries Act.	The wetlands of West Bengal were protected,
		and wetland area >0.035 hectare could not
		be destroyed under this act.
1994	Environment Impact	E.I.A. was made compulsory for any cons-
	Assessment (E.I.A)	truction under E.P.A, 1986 and subsequently
	statement notification	the list of industries requiring E.I.A was
		published.
1994	Modification of Coastal	The minimum distance for the high tide line in case of tidal rivers was reduced to 50m
	Regulation Zone.	
	1 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	under the E.P.A, 1986. Under E.P.A 1986.
1995	National Environmental	Under E.r.A 1980.
1007	Tribunal Act. Hazardous Waste and	The hazardous chemicals were clearly de-
1996	Chemicals (Amendment) rules	markated under E.P.A 1986.
1997	E.I.A (Second modification).	Provision of public hearing was introduced.
1997	Biomedical Waste Disposal	The disposal of biomedical waste was men-
1990	Rule.	tioned (under E.P.A, 1986).
2000	Biodiversity Act	Protection of biodiversity in India.

13.10.1. GREEN BENCH AND ITS ROLE:

In order to monitor environmental problems in the states in an effective manner, the Supreme Court of India decided to establish Green Benches in State High Courts, who will deal with environment related problems. Accordingly, the Green Bench in Calcutta High Court started functioning since June, 1996 and it meets at least once a week to give verdicts in environment related problems.

Immediately after inception, the Supreme Court transferred 68 cases of industrial pollution and tannery related problems to the Green Bench of Calcutta High Court. In other states, the Green Bench does not exist separately by name, but a particular Division Bench of the State High Court deals with the environment related problems. Since 1996, the number of cases dealt by the Calcutta High Court's Green Bench had increased progressively and presently around 250 cases on environmental pollution is being dealt with.

Domain: The Green Bench not only deals with petitions filed by industries or organizations, but also by individuals aggrieved by the action of regulatory authorities like local municipality, state pollution control board *etc.* It also deals with petition or just an informal written application by a single individual against statutory authorities for restoring the states of water bodies, canals, rivers, lakes *etc.* It also apppoints officers to look after the fact that whether the verdicts are strictly enforced or not.

The major areas dealt by the Green Bench are as follows:

- (i) Industries violating environmental norms.
- (ii) Illegal filling up of water bodies.
- (iii) Injudicious cutting/felling of trees.
- (iv) Auto-emission cases.
- (v) Health hazards and biomedical waste.
- (vi) Dumping and non-clearance of garbage.
- (vii) State of hospital and other morgues/crematorium.
- (viii) Maintenance of parks and lakes.

Major Verdicts given: Some of the major verdicts given by Calcutta Green Bench are:

- (i) Prohibition of indiscriminate use of microphones and loudspeakers particularly during examination season.
 - (ii) Prevention of selling and use of banned fire works (above 90 dB).
 - (iii) Specification of Silence zones.
 - (iv) Prevention of cutting of trees within city.
 - (v) Probibition of filling of water bodies for any reason.
 - (vi) Environment Impact Assessment is mandatory for any construction.

13.10.2. POLLUTION CONTROL BOARDS:

The first step towards the establishement of the Central Pollution Control Board was initiated in the year 1970 by the then Prime Minister Mrs. Indira Gandhi with the appointment of committees looking after the environment related issues. The sequence of events took place in the following chronological order.

1970-Committees under the Planning Commission were constituted for looking after the environmental issues.

1974 Central Pollution Control Board was established in September to enforce the Water pollution act 1974 and subsequently the Air pollution act, 1981 and Environment protection act, 1986 were brought under its purview.

1974-75 Establishment of the State Pollution Control Boards.

1980-The Department of Environment was constituted.

Duties of Central Pollution Control Board:

The Central Pollution Control Board (CPCB) has the following duties:

- (i) To advise the Central government in setting of pollution polices.
- (ii) To spread the general information of environmental awareness to common people.
- (iii) To provide technical and research assistance to the different State Pollution Control Boards.
 - (iv) To execute nationwide programme on pollution control of air, water and land.
 - (v) To ensure compliance to various environmental protection acts and regulations.
 - (v1) To declare and modify the emission standards.

Achievements of CPCB:

Since its inception in 1974, the CPCB have acheived in a major way in the control of environmental pollution, they are as follows:

- (1) Strict enforcement of Water Pollution Act, 1974, Air Pollution Act, 1981 and Environment Protection Act, 1986.
- (ii) Improved the air quality in the capital city of India i.e. New Delhi through the introduction of Compressed Natural gas (CNG) as the major vehicular fuel.
- (iii) They have established the National Ambient Air Quality Monitoring Cell (NAAQMC) to maintain a strict vigil on the air quality standard.
- (iv) Establishment of Automobile Monitoring Centers in the urban areas, who are engaged in the measurement of O₂, CO, SO₂ and NO₂.
- (v) They have set up Water Quality Mangament Centres (WQMC) within the country, whose main job is to monitor 14 major rivers, 44 medium and 55 minor rivers of the country.
- (vi) They have started the **Ecomark Scheme** in India, by which the eco-friendly products of the country are labelled.
 - (vii) They have categorized 17 major polluting industries in India.

State Pollution Control Boards (SPCB):

The State Pollution Control Boards were established closely after the establishement of CPCB. They mainly work under the guidelines of CPCB to alleviate the atmospheric pollution within the state.

Duties of SPCB:

- (i) Execution of the nation wide programme of CPCB within the state.
- (ii) To advise the state government on pollution related matters.
- (iii) Arranging of training and awareness camps at different levels within the state.
- (iv) To state and modify emission standards for particular cases within the state, like the problems of arsenic in drinking water, suspended particulate matters in West Bengal.
- (v) To take legal action against the defaulters, which ultimately may lead to the closing down of the unit.
- (vi) To provide technical assistance for the treatment, disposal and utilization of sewage and industrial effluents.

(vii) To categorize industries as per CPCB into red, orange and green categories with respect to their polluting abilities:

(a) Red category: Highly polluting type, not allowed to operate within the municipality area of metropoliton cities, e.g., fermentation, sugar, fertilizer, oil refinery.

- (b) Orange category: They are allowed, with respect to strict pollution control devices. e.g., servicing of motor vehicles, processing of food grains, fish processing units.
- (c) Green Category: They have low polluting standards and are normally allowed within the city limits. e.g. atta chakki, bakery etc.

13.10.3. EARTH SUMMIT:

The Earth Summit is the reaction of the United Nations against the global environmental degradation. The first such attempt was initiated in the form of a global conference in 1972 and heads of States or their representatives from 113 countries met at Stockholm in 1972, then at Nairobi in 1982, Rio-de-Janeiro in 1992 and Johannesburg in 2002. From 1992, these global environmental conferences attained the status of Earth Summit. The major outcomes of these summits are discussed below:

[1] Stockholm Conference: This conference was the first novel attempt to unite the world under one common agenda of environmental protection in 1972. The Heads of states or their representatives froms 113 different countries attended the conference. Our prime minister at that time Mrs. Indira Gandhi gave the slogan of alleviation of 3 Ps of environment *i.e.*, population, poverty and pollution. Its declaration included 26 principles and 109 recommendations. The Man and Biosphere programme was initiated by United Nations in the following year (1973), which stressed on biodiversity conservation by the introduction of Biosphere Reserve.

[2] Nairobi Conference: The conference venue was selected in Africa in order to ensure it's all round development in terms of poverty, literacy, food production. It was attended by the representatives of 145 countries. The stress on biodiversity continued, along with that, the movement of preserve planet Earth was initated, health for all, exploitation of non-conventional energy resources were initiated. The Ministry of Environment and forest was created. The Bartland Commission on sustainable development was created and the recommendations were submitted in 1987 in the form of a text "Our Common Future".

[3] Rio Conference: This conference for the first time was referred to as the global summit, because of the widest participation and importance of the environmental issues considered.

It was held in Rio de Janeiro in June, 1992 and was attendeed by 178 countries all over the world. Five separate agreements were signed by the participating countries, which were as follows:

(i) A framework convention on climate change was taken up considering it as a serious problem, which was particularly with respect to the green house effect.

(ii) The convention on biological diversity was organised to preserve biodiversity throughout the planet.

(iii) An action plan in the form of Agenda 21 was formulated. It had 40 chapters and was aimed at the sustainable development in the 21st century.

(iv) The Rio-declaration comprising of 27 principles was formulated as the guiding action on environment.

(v) The forest principles were finalized and it was considered as the guiding principle

for forest management and exploitation.

The Rio-Summit got very high media partronge and maximum number of heads of states, but ultimately it was in vain, because several countries did not sign the accord of reducing the use of CFC (chloro fluoro carbon) which resulted in the depletion of ozone layer. The developed countries blamed the developing countries for the CO₂ emission, while they themselves did not take any suitable measures for reducing CO₂ emission. The trouble became more acute, when U.S.A and U.K. did not sign the **Kyoto protocol**, meant for reducing the CO₂ emission and blamed the 3rd world countries for liberating CO₂ and causing global warming.

[4] Johannesburg Conference: It took place in Johannesburg, South Africa, between 23rd August and September 2nd, 2002. It was attended by 191 coutries and more than 21 thousand delegates including W.T.O (World Trade Organization) and

World Bank officials and 82 Heads of states.

The areas of discussion were divided into five major areas, which were as follows:

(i) Water and Sanitation.

(ii) Energy.

- (iii) Health and Environment.
- (iv) Agriculture.

(v) Biodiversity and Ecosystem.

The Agenda 21 of the Rio-decleration was implemented in 10 major chapters, that included:

Introduction, Poverty, Production, Natural resources, Sustainable development, Health, Small island states, Africa, Institutional development and Means of implementation.

The Johannesburg decleration included the following points:

(i) Eradication of poverty by 2015 from the globe.

(ii) World solidarity fund will be set up for the purpose of eradication of poverty.

(iii) Water quality will be improved and sanitation facilities will be provided to the underdeveloped countries.

(iv) Renewable energy to be increased by 14% by 2008.

(v) Every person or nation should get equal acess to energy, this definitely brought to light the inequality existing between the developed and developing nations in terms

of energy management.

The Summit brought into light the racial inequality of Zimbabwe, the problems of genetically modified food, loss of bidiversity, the issue of bio-terrorism. In terms of business, it was quite productive, because nearly 200 partnership treaties were signed under the auspicion of the W.T.O, which even included the Indian company Sulabh International, that grabbed the order of sanitation development in Zimbabwe. But in terms of environmental protection, nothing concrete was achieved, the rift between the developed and developing countries increased further and even the G-37 (A body of 37 developed nations) along with European Union stood against the USA in the issues of CO₂ emission and G.M. (Genetically Modified) food. So it can be concluded that the Johannesburg Summit gave us nothing special but lot of commitments, which are yet to be fulfilled.

13.11. Matters to Recollect

- ** The wood 'Ecology' was comed by E. Haeckel (1866)
- Ecology is a subject dealing with the study of habitat of organisms.
- Study of individual organism with respect to the nature is autecology.
- Study of a group of organisms in relation of nature is synecology.
- Community represents an assemblage of organisms and represents the ecological unit.
- There are five major types of plants in a community.
- The replacement of one group of organisms by another group of organisms in a particular habitat is known as succession.
- Succession can be primary or secondary in nature.
- The serial communities growing temporarily are called ecoseres.
- The final community which becomes stable in a particular habitat are called **climax** community.
- Ecosystems are functional units of ecology, where the biotic and abiotic factors are in close interaction.
- The green plants can utilize solar energy and can prepare their own food and are known as **producers** of ecosystem.
- The animals depend directly or indirectly on the green plants and are called consumers, which may be primary, secondary or tertiary in nature.
- The micro-organisms are responsible for decay and decomposition of dead plants and animals and are called **decomposers**.
- The producers, consumers and decomposers constitute the biotic phase.
- The transfer of food from one tropic level to the higher level is known as food chain, which represents the linear food-predator relationship in an ecosystem.
- The food chains are mainly of three types viz. grazing, detritus and parasitic.
- Many food chains of a particular habitat remain interconnected to form a complicated network called food web.
- The pyramidal representation of an ecosystem is known as ecological pyramid.
- Ecological pyramids are mainly of three types, viz. pyramid of number, pyramid of biomass, pyramid of energy.
- Each step of an ecological pyramid comprising of specific type of organisms are called trophic levels.
- There is a progressive decrease in the energy at every trophic level of an ecological pyramid.
- The producers can only utilize 0.1% of the total solar energy encountered by them annually.
- The energy flow is unidirectional.
- Biogeochemical cycles involve the cycling of material between the biotic phase and geophase.
- Biogeo chemical cycles include hydrologic cycle, gaseous cycle and sedimentary cycle.

- Biosphere reserve was launched in 1973 under the Man and Biospheree programme.
- A biosphere reserve include the core zone, buffer zone I and II and manipulation zone.
- The first biosphere reserve came up in India in 1986 in the Nilgiris.
- Sundarban biosphere reserve has a national park, a tiger reserve and 3 wild life sanctuaries.
- Any change in environment which is harmful for man is called pollution.
- Agents responsible for pollution are called pollutants.
- Decrease of O, and increase of other gases or particulate matters in the atmosphere is called air pollution.
- Air pollution is mainly caused by industrial and automobile exhausts.
- Air pollution mainly affects the respiratory system.
- Water population is mainly caused by mixing of industrial effluents, domestic sewage and surface runoff with water bodies.
- Water pollution mainly affects the digestive system.
- Mixing of any substance with soil that reduces productivity of soil is called soil pollution.
- Increase in unwanted sound or noise in the environment is called **noise pollution** or **sound pollution**.
- Noise pollution primarily affects the auditory apparatus.
- Gamma rays and X-rays are primarily responsible for radioactive pollution.
- Biomagnification involves increase of a particular pollutant along the food chain.
- Bioaccumulation is deposition of a pollutant in a particular species.
- Lead causes osteolysis, dislexia and anaemia in man.
- Cadmium causes Itai Itai disease, common obstructive pulmonary disorder.
- Mercury caused the Minamata disease in Japan.
- Green house effect is caused by ozone depletion and accumulation of green house gases.
- Photochemical among cause breathing distress in aged people and young children.
- Acid rain causes stone cancer.
- **BOD** of water bodies increases due to sewage pollution.
- COD increases due to increase in industrial pollution.
- Thermal pollution is maximum in stagnant water bodies.
- Industrial pollutants can be treated by specific physical and chemical methods.
- Wetland involves recharging of ground water, prevents water stagnation.
- The Water Pollution Act 1974, Air Pollution Act of 1981, Environmental Protection Act of 1986 and the Wild life Protection Act of 1991 are the most stringent environmental protection acts.
- Green Bench was initiated in Calcutta High Court in 1996, which deals with environment protection.

- Central and state pollution control boards were initiated in 1974 responsible for air and water quality assessment and laying down emission standards.
- Earth Summit was initiated in Stockholm in 1972.
- Agenda 21 came up in Rio Summit in 1992.
- The last summit was as Johannesburg in 2002.

13.12. Summary

The word Ecology is derived from Greek world Oikos meaning habitat and logos meaning study. It has two major branches-Autecology and Synecology. Community represents an assembly of organisms in a particular habitat, Succession is replacement of one community by the other and it can be primary or secondary in nature. Succession results in intermediate stages or ecosere and ultimately the emergence of a climax community. The ecosystem is the functional unit of ecology. in which there is interaction between the biotic or living and abiotic or non-living components. The abiotic components may be organic or inorganic in nature. The biotic components include the producer, consumer and decomposers. The producers are represented by green plants, which utilize solar energy by photosynthesis and prepare their food. The animals are the consumers, which depend directly or indirectly on the producers for their nourishment. They may be primary. secondary or tertiary in nature. The decomposers cause decay of the plants and animals after their death and there by helps in recycling. The linear food-predator relationship in an ecosystem is food chain. An aggregation of several food chains forming a complex network is a food web. The pyramidal representation of an ecosytem with the producers at the base and the primary, secondary and tertiary consumers on its top is known as ecological pyramid. Each step of an ecological pyramid is known as trophic level and there is reduction of energy at each trophic level and it can be governed by the 10% law. The ecological pyramids are of 3 types viz. pyramid of number, pyramid of biomass and pyramid of energy. The energy flow in an ecosystem is always unidirectional from producers to the tertiary consumers. The biogeochemical cycles operate in the nature and explains the recycling of various elements. The biosphere reserve was launched in 1973, in the world and in 1986 in India. It includes the core zone, buffer zone (I and II), and manipulation zone. The Sundarban biosphere reserve mainly helps in Royal Bengal Tiger conservation.

When the environment becomes harmful to human health due to increase or decrease of its constituents or entry of any new material into it, the phenomenon is called 'pollution'. The chief reasons for pollution are—continual increase of population, development of cities, towns and industries without proper planning, random deforestation and killing of animals and misuse of science and technology for economic prosperity. An agent causing pollution is called pollutant. Pollutants are of three categories—chemical, physical and biological. Pollutant may again be degradable or non-degradable. The main types of pollution that we have to face are-air pollution, water pollution soil pollution, noise pollution and radioactive pollution.

When any change in atmospheric composition becomes harmful to us, it is called

air pollution. Air is polluted by smoke, fog, smog. dusts, biocides, microbes (bacteria, virus etc.), radioactive materials and solar rays. Air pollution may cause bronchitis, asthma and various other respiratory diseases, inflammation of eyes, skin diseases and neural disorders. For prevention of air pollution, origin of pollutants should be restricted, purification of air should be done and residential places should be at a safe distance from the factories.

When due to mixing of something in water makes it unsuitable for human use, it is called water pollution. The chief pollutants are industrial effluents, domestic sewage and surface runoff. Misuse of water reservoirs or streams (washing and bathing) also cause water pollution. Consumption of polluted water may cause enteric diseases, jaundice, hepatitis etc. Bathing in polluted water may produce infection of eye, ear and skin. Water pollution can be prevented by treatment of industrial effluent and sewage before it is allowed to enter into rivers, modernisation of sewerage system, prohibition of misuse of water reserviors and restriction in the use of pesticides. The drinking water should be properly filtered and disinfected.

Any substance that reduces the productivity of soil is called soil pollutant and presence of such substances in soil is called **soil pollution**. Soil is polluted by biocides, industrial wastes, domestic garbage, solid wastes *etc*. Soil pollution decreases vegetation and disturbs ecosystem. Some pollutants may enter the food chain. In order to prevent this, proper disposal and recycling of wastes is necessary.

Increase of unwanted sound (or noise) in the environment is known as **noise** pollution or sound pollution. The chief sources of noise pollution are industrial noise, vehicular noise, social or domestic noise etc. Noise pollution impairs auditory sensation and leads to early partial deafness. It also produces various mental and physical abnormalities. For prevention of noise pollution, the source of sound should be reduced, sound proofing methods are to be applied and finally ear plugs or ear muffs may be used.

Over exposure to ionizing radiations is referred to as **radioactive pollution**. It is mainly caused by the use of radioactive materials and X-rays. Ionizing radiations produce various diseases including leukemia, cancer *etc.* and may even produce genetic defects in future generations.

Biomagnification of a pollutant occurs in a food chain, while bioaccumulation occurs in a particular individual due to overexposure. Lead, mercury and cadmium cause specific metabolic disorders in man. Green house effect is primarily caused by depletion of ozone layer due to CFC and accumulation of green house gases. Photochemical smog is caused by peroxy acetyl nitrate, causing respiratory distress in young children and aged people. Acid rain is caused by accumulation of acid vapour, which damages buildings. Treatment of industrial pollutants involves specific chemical treatment. Wetlands serve as the kidney of nature helping in recharging of ground water. The major environmental protection acts include Water Pollution Act, Air Pollution Act, E.P.A and Wildlife Protection Act, The Green Bench, initiated in 1996, in Kolkata deals with pollution related cases. The Central and State Pollution Control Boards usually look after the enforcement of environmental regulations. Environmental Summit was initated in 1972 in Stockholm, which is popularly called Earth Summit and considers the global environmental issues. Agenda 21 was formulated in the Rio Summit and aimed towards sustainable development in the 21st century.

13.13. Naming/Discovery/Discoverer

- (1) E. Haeckel (1866) comed the word 'Ecology'.
- (2) Sechroter (1895) proposed the term Autecology and "Synecology".
- (3) Willis (1922) proposed the Age and Area Hypothesis.
- (4) E. Transeau (1926) gave the concepts of net productivity and gross productivity in an ecosystem.
 - (5) C. Elton (1927) gave the concept of ecological pyramid.
- (6) **D. Prain** (1932) gave a vivid description of flora of Bengal in a monograph called Bengal plants, which also included the detailed account of the mangrove plants.
 - (7) C. Raunkiaer (1934) gave the classification of plant communities.
 - (8) Tanslay (1935) comed the word ecosystem.
 - (9) D. Chatterjee (1939) for the first time denoted endemism in India.
 - (10) C. Elton (1939) referred the primary carnivore as the key industry animals.
 - (11) R. Lindemann (1942) denoted the model of energy flow in an ecosystem.
 - (12) Dansereau (1957) gave the modern classification of biotic community.
- (13) E. Odum (1959) gave the concept of interaction between the biotic and abiotic components of an ecosystem.
- (14) **Kendeigh** (1967) explained the inter-relationship between the living organisms of an ecosystem.
 - (15) Woodwell (1967) denoted biomagnification of DDT in a marine ecosystem.
- (16) Edwards and Lofty (1922) denoted the non-target effects of nematicide on earthworm.
- (17) E. Odum (1975) gave the modern classification of macro-ecosystems depending on the basis of energy flow.
 - (18) Dugan (1990) gave the detailed classification of wetlands.

13.14. Answers to Special Questions

[1] What is Ecosystem?

[J.E.E. 1990, '92]

Ans. Ecosystem is the basic functional unit of ecology that deals with the interaction and interrelationship between the living and non-living components of an ecosystem.

[2] What are tertiary consumers?

Ans. The consumers which feed on secondary consumer e g. Snake in a grassland ecosystem.

[3] What is detritus?

Ans. The decaying organic matter formed after the death of plants and animals is known as detritus.

[4] What are nektons?

Ans. They are floating animals having the power of locomotion. e.g. Paramoecium.

[5] What will happen to an ecosystem if the number of producers are less than that of the consumers?

[J.E.E. 1996]

Ans. The coosystem will become unstable and there will be intra-specific struggle for food.

[6] Name the organisms present in detritus food chian.

Ans. Bacteria, fungi, protozoa, insects, mites, crustacea, molluscs.

- [7] What is food chain?

 Ans. The linear food predator relationship from producer to tertiary organisms is known as food chain.
- [8] Why there is loss of chemical energy in each step of ecological pyramid?

 Ans. This loss of energy is following the second law of thermodynamics, when every time the energy is transferred from one organism to the other, a part of this energy is lost in the form of heat.
- [9] What is succession? What are its different types?

 Ans. When one group of organism is replaced by another group of organisms in a particular habitat, it is called succession. It can be primary or secondary in nature.
- [10] What is ecosere?

 Ans. The intermediate communities formed in a particular habitat before the climax community is established is known as ecosere.
- [11] What is endemism?

 Ans. When a particular species remain confined in a particular geographical area due to natural barriers. e.g. Ginkgo in Korea and Japan.
- [12] What is the amount of energy utilized annually by the producers?

 Ans. One green plant utilizes only 0.1% of the energy encountered by it annually.
- [13] Name 2 endemic species of India.

 Ans. Aegle marmelos. Ficus benghalensis.
- [14] What are the different types of individuals in a population?

 Ans. There are 3 types of population stages viz Pre-reproductive, Reproductive and Post-reproductive.
- [15] What is a food pyramid?

Ans. The pyramidal representation of a food chain with the producers at the base and consumers on top of it, is known as a food pyramid.

- [16] What is a reservoir pool and cyclical pool? [J.E.E. 1983]

 Ans. In an ecosystem, the elements which always remain in the abiotic phase and do not pass into the biotic phase is known as reservoir pool. But the elements which rotate in the cycle between the biotic and abiotic phase is known as cyclical pool.
- [17] What is ecological niche?

 Ans. The position and function of an organism in a particular habitat of the ecosystem is known as ecological niche.
- [18] What are the various types of ecological niches?

 Ans. There are mainly three types of ecological niches viz. spatial, trophic and multivariant niche. The multivariant niche can again be classified as fundamental and derived niche.
- [19] What are the different types of biogeochemical cycles?

 Ans. The are 3 types of biogeochemical cycles, which include the water or hydrologic cycle, gaseous cycle (carbon, hydrogen, nitrogen) and the sedentary cycles.

[20] What are the major events of nitrogen cycle?

Ans. The major events of nitrogen cycle are ammonofication, nitrification, denitrification and nitrogen fixation.

[21] What is Biosphere Reserve?

Ans. They are undisturbed areas of nature meant for scientific study, where human interferences are under control.

[22] What are the major areas of Biosphere Reserve?

Ans. There are four major areas of Biosphere reserve, which are the innermost core zone or Sanctum sanctorum, the buffer zone I and II and the manipulation zone.

[23] What is pollution of environment?

[J.E.E. 1985; '88; '93]

Or

What is pollution?

[Tripura H.S. 1997; '98]

Ans. Pollution of environment means addition of extraneous materials in an environment as a by-product of man's activity leading to a detrimental change in the physical, chemical and biological characteristics of the environment.

[24] How the environment is polluted?

[Tripura H.S. 1983]

0r

Mention the major causes of pollution.

Ans. The environment is polluted due to the following reasons:-

(i) Continuous growth of population; (ii) Unscientific and unplanned urbanisation and industrialisation; (iii) Random deforstation and killing of animals; (iv) Misuse of science and technology by man for greater monetary profit.

[25] How pollution can be controlled?

[Tripura H.S. 1983]

Ans. (i) Pollution is due to man made nuisance, which in turn in proportional to the population. So, in order to control pollution, the population explosion has to be checked first.

(ii) Industries are the main source of pollution; so, industries should be planned properly. They should be away from residential areas. Their wastes should be properly treated before being released into the environment.

(iii) Cities and towns should be properly planned so that the sewage is not allowed to mix with the rivers, lakes etc. directly without treatment.

(iv) The emission of smoke and noise from various sources are to be restricted to minimum.

(v) Use of pesticides, herbicides, insecticides and other poisonous chemicals in agriculture *etc.* is to be restricted. Biological control of pest is to be encouraged.

(vi) Waste recycling should be encouraged.

(vii) The government should from bodies for pollution control (e.g. pollution control board etc.) and should frame proper 'Acts and Laws' to minimise pollution and these laws should be strictly implemented.

(viii) Finally, the people should be properly educated and made aware of the causes, harmful effects and preventive measures of different types of pollutions, because without public consciousness, pollution control is impossible.

[26] What do you mean by the term 'pollutants'?

Ans. The agents causing pollution or the polluting agents are called pollutants.

[27] What do you mean by degradable and non-degradable pollutants? Give examples.

Ans. Pollutants that are easily and rapidly decomposed by natural or artificial means and may be recycled are called degradable (or biodegradable) pollutants. Such pollutants are less stable and do not persists in the environment for a long time. Examples are—domestic wastes (sewage), dead organisms etc.

The materials and poisons that either do not degrade or degrade very slowly in natural conditions are called non-degradable pollutants. Naturally, they persist in the environment for a long time and their harmful effects are severe and far reaching. Examples are—aluminium, plastic bags, mercuric salts, long chain phenolic compounds, pesticides like DDT, aldrine etc.

[28] What is PAN?

[J.E.E. 1997]

Ans. PAN is peroxy acetyl nitrate formed by reaction of hydrocarbons with

oxides of nitrogen in air in presence of sunlight. It is a poisonous material which causes atmospheric (air) pollution. Its harmful effects include irritation of eyes and throat, respiratory troubles, lung cancer and destruction of vegetation.

[29] What are the principal pollutants that are responsible for the Ganges water pollution? If the control of t

ammonia, cyanides, heavy metals (e.g. Hg, Cd etc.) and hot water.

(ii) Domestic sewage containing excreta, washings of bathroom and kitchen

with detergents, germs etc.

(iii) Water drained from agricultural lands containing fertilisers, herbicides, pesticides etc.

(iv) Rain water carrying the minerals like Pb, Cu, As etc. present in earth's

rust.

(v) Waste materials added to the river by man made nuisance e.g. defecation, bathing of man and animals, washing of clothes and untensils, throwing of dead bodies of man and animals etc.

(vi) Silt accumulation.

- [30] (a) Mention three causes of air pollution (b) State the measures for control of air pollution (Three measures to be mentioned). [J.E.E. 1993]

 Ans. (a) Causes of air pollution.
 - (i) Release of smoke from automobiles, industrial exhausts and furnaces into the atmosphere, and accidental gas leaks from industries.
 - (ii) Spraying of biocides (pesticides, insecticides etc.).
 - (iii) Deforestation.
 - (b) Measures for control of air pollution:
 - (i) Prevention or restriction of emission of smoke from industries and automobiles by using natural gas, electricity etc. as the source of energy.
 - (ii) Use of electrostatic precipitators, scrubbers, filters etc. for purification of air by removing dust, smoke and gases from the air.
 - (iii) To practice aforestation and social forestry (or plantation in the cities) for minimising CO, in air.

[31] Name two very low-cost methods a common man can adopt to keep the river Ganga clean. [J.E.E. 1987]

Or

Suggest two methods which can be adopted to keep the river Ganga clean.
[J.E.E. 1997]

Ans. (i) Dropping of domestic sewage or household effluents into the river should be stopped.

(ii) Washing of clothes, bathing of cattle, throwing of garbage, deadbodies etc. as well as throwing of flowers and leaves after the 'Pujus' into the river should be stopped.

[32] Name two air pollutants, their sources and effects on man.

Ans. Two most common air pollutants are *smoke* and *dust*.

Source-Smoke originates mainly from industries and automobiles due to combustion of fuel. Domestic combustion of coal, wood and oil also produces smoke. *Dusts* are produced mainly from industries *e.g.* mines, foundry, quarry, pottery, textile, wood and stone working industries. Dusts also come from natural sources *e.g.* wind borne dust. Dust may be of inorganic (*e.g.* silica, mica, coal, asbestos *etc.*) or organic (*e.g.* cotton, jute, cane, hay *etc.*) type.

Effects-Smoke affects the respiratory tract and produces respiratory diseases like bronchitis, asthma, emphysema etc. Dusts also affect lungs on being inhaled, and produce the lung disease known as pneumoconiosis. In this disease, a layer of fine particles of dust is deposited within the lungs, which produces respiratory distress.

[33] (a) What is photochemical smog? (b) Why is it harmful for human health?

Ans. (a) Photochemical smog is a secondary air pollutant containing poisonous materials like ozone gas, peroxy acetyl nitrate (PAN), aldehydes etc. that are formed by reaction of nitrogen oxides and hydrocarbons of smoke in air in presence of UV-rays of sunlight.

(b) It adversely affects the lungs causing bronchitis and respiratory distress. The PAN may cause lung cancer. Smog irritates the eyes and produces burning sensation in the eyes.

[34] Name the common air pollutant gases.

Ans. (i) Oxides of carbon (carbon dioxide, carbon monoxide), (ii) Oxides of nitrogen (nitrogen monoxide, nitrous oxide), (iii) Oxides of sulphur (sulphur dioxide, sulphur trioxide), (iv) Hydrogen sulphide, (v) Methane.

(a) What is pneumoconiosis? (b) What are its common types?

Ans. (a) Pneumoconiosis a lung disease caused by inhalation of dusts due to exposure to the dusts for variable periods. It is an occupational hazard and is seen in industrial workers of various kinds. In this disease, a layer of fine dust particles is deposited within the lungs, which gradually cripples a man by reducing his working capacity due to lungs fibrosis and other complications.

(b) Pneumoconiosis may be of various types depending on the kind of dust particle to which the subject is exposed. The common types of the disease are—Anthracosis or Black lung disease (due to coal dust, in coal miners), Silicosis (due to silica dust, in stone cutters), Asbestosis (due to asbestos fibres, in pipe fitters), Siderosis (due to iron dust), Baggasosis (cane fibre), Byssinosis (cotton dusts), Farmer's lung (hay or grain dust) and Tobacossis (tobacco dust).

[36] (a) What is noise pollution? (b) What are its ill effects on humans?
[J.E.E. 1991]

Ans. (a) Increase of noise or meaningless, undesirable, loud and displeasing sound in the surroundings is called noise pollution or sound pollution.

(b) Ill effects of noise pollution on man: Noise exerts two types of ill effects on man.

(1) Direct effects or Auditory effects: They include—(i) hearing impairments and auditory fatigue associated with whistling and buzzing in the ears; (ii) Deafness or loss of hearing or early presbycusis.

(2) Indirect effect or Non-auditory effects or Side effects: These include—(i) Interference with speech and communication. (ii) Mental upsets such as annoyance, nervousness, irritability (ill tempered), violent behavior, nervous breakdown etc. (iii) Physiological changes e.g. palpitation, hypertension, anxiety, insomnia, nausea, dizziness, anorexia. hyperglycemia etc. (iv) Loss of working efficiency due to loss of concentration.

[37] What are the side effects of sound pollution? [J.E.E. 1995]
Ans. See answer to Q-36 (b) Point no. 2 only.

[38] Name some hygienic effects of noise pollution. [J.E.E. 1996]

Ans. See answer to Q-36(b).

[39] Name the sources of sound pollution, [J.E.E. 1996]

What are different causes or sound pollution? [J.E.E. 1998]

Ans. (i) Use of loudspeakers, amplifiers, blaring radios, televisions, generators etc.

(ii) Increasing sound of vehicles e.g. motor cars, trucks, buses, motor cycles, trains etc.

(iii) Sound of aircraft engines, supersonic aeroplanes.

(iv) Noise of industries originating from working of machines.

[40] (a) What are the hazards of sound pollution? (b) State the important points of prevention as per Hon'ble High court order in our state. [J.E.E. 1998] Ans. (a) See answer to Q-36 (b).

(b) (i) Some specific prohibitory orders have been promulgated against production of sound beyond permissible levels. (ii) Production of sound beyond 90 decibel unit is prohibited and constant noise by human agencies is also restricted. (iii) The court order has banned the use of loud sound systems like audio instruments, microphones, etc. and bursting of crackers in festivals.

[41] Write the full names of-PAN, MIC, WHO, BOD, COD, DDT, CFC and CPCB.

Ans. PAN-Peroxy acetyl nitrate.

MIC-Methyl isocyanate.

BOD-Biochemical oxygen demand.

COD-Chemical oxygen demand.

DDT-Dichloro diphenyl trichloro ethane.

CFC-Chlorofluorocarbon.

CPCB-Central pollution control board.

- What do you mean by heat island? [42]
- Ans. Increase in concentration of suspended particles in the lower atmosphere reduces or stops rainfall at that region. Such localised areas remain too hot even in the scheduled rainy seasons. Such localised urban areas are called heat islands.
- What type of pollutants are PAN and smog? (a) Primary pollutant, (b) Secondary pollutant, (iii) Degradable pollutant. 1431 Ans. Both PAN and smog are secondary pollutants.
- Which of the following is measured by BOD? (a) Industrial pollution, (b) Air pollution, (c) Water pollution. [44] Ans. Water pollution.
- [45] Bhopal gas tragedy was due to leak of which gas? (a) Methyl isocyanate, (b) Phosgene gas, (c) Nitrogen peroxide, (d) Sulphur trioxide.
- Ans. Methyl isocyanate. Which of the following is not produced by motor vehicles? [46] (a) CO₂ (b) Hydrocarbon gases, (c) Flyash, (d) CO. Ans. Flyash.
- For which one of the following, the O₃ present in atmosphere is responsible? (a) Increasing the global temperature, (b) Supply of O, for people travelling [47] in jet, (c) Hindering higher rate of photosynthesis, (d) Checking penetration of U-V rays. Ans. Checking penetration of U-V rays.
- Pollution is not caused by the use of which of the following as fuel? [48] (a) Wood, (b) Solar energy (c) Methane, (d) Sulphur di-oxide.
- Ans. Solar energy. Which one of the following is the most dangerous air pollutant? [49] (a) CO₂, (b) CO, (c) N₂, (d) SO,
- Ans. CO. Which one of the following is the main cause of water pollution? [50] (a) Smoke, (b) Industrial effluents, (c) Sewage, (d) Mathura refinery.
- Ans. Industrial effluents.
- What are aerosol pollutants? [51] Ans. Aerosol means a colloidal system in which solid or liquid particles are suspended in gas. Aerosol pollutants are chemicals released into the air with force in the form of mist or vapour. Such pollutants originate from jet propellants, sprays etc. These contain fluorocarbons which may affect the atmosphere by depleting the stratospheric ozone layer.
- How pesticides and insecticides cause environmental pollution? [52] Ans. (i) Pesticides and insecticides are used in agriculture, storage of food, mosquito control etc. by spraying them. This causes air pollution and affects those who are using these chemicals.
 - (ii) The pesticides also cause soil pollution when they mix with the soil, and enter into crops and plants.
 - (iii) These chemicals cause water pollution by mixing with a river through the rain water draining from the agricultural fields.

- (iv) These chemicals are not easily destroyed in nature (i.e. they are non-degradable pollutants). Plants and crops contaminated with such chemicals cause food pollution as these chemicals enter into the food chain.
- What is decibel? How is it related to noise pollution?

 Ans. Decibel (dB) is the unit of intensity of sound. It is represented as log₁₀ ratio of I and I₀, where I is the actual intensity and I₀ is the reference intensity. Sound intensities upto 60 dB are not harmful to us. A sound with an intensity of 80 dB or more is known as noise and causes sound pollution or noise pollution.
- [54] What is biomagnification?

 Ans. It denotes the enhancement in the concentration of a particular substance along the food chain. e.g. DDT.
- [55] What is bioaccumulation?

 Ans. The phenomenon of accumulation of toxic substances in the body of living organism is known as bioaccumulation.
- [56] What are phytochelatins?

 Ans. The complex proteinaceous compounds that binds with toxic heavy metals are known as phytochelatins.
- [57] What is Itai-Itai disease?

 Ans. It is a disease caused by entry of excess cadmium into human body. It is marked with the symptoms of back pain, rheumatism, osteomalacia, loss in body weight, proteinuria, glaucoma and ultimately death.
- [58] Name the bacteria that can convert elemental mercury to methyl mercury.

 Ans. Clostridium cochlearum in anaerobic condition, Pseudomonas sp. in aerobic condition convert elemental mercury to methyl mercury.
- [59] What are the agents that cause ozone depletion?

 Ans. The various agents that cause ozone depletion are nitric oxide, hydroxylion and chlorine atoms.
- [60] What is BOD?

 Ans. Biological or biochemical oxygen demand (BOD) is the amount of oxygen required by micro-organisms to decompose organic matter present in water kept at 25°C for 5 days in an incubator.
- [61] What are the different types of wetlands?

 Ans. Wetlands are classified into four major types as denoted by Dugan (1990), they are marine wetland, estuarine wetland, lagoons and salt lakes.
- [62] What is the most powerful environment protection act?

 Ans. The environment protection act (EPA) of 1986 in the most powerful environmental protection act, which was revised in 1994.
- [63] What is Green Bench? When was it established?

 Ans. The Green Bench is a particular Division bench of Calcutta High Court, which deals with matters related to environmental pollution. It was created by the Supreme Court in June, 1996 and its meets at least once a week to deal with environmental pollution related problems.
- [64] Why was CPCB established?

 Ans. The CPCB was established is 1974 by the Government of India, to enforce the Water pollution Act of 1974, Air Pollution Act, 1981 and the Environment Protection Act, 1986.
- [65] What was the venue of 2002 Earth Summit? What were its major domain?

 Ans. The Johannesburg is South Africa was the venue for 2002 global summit on environment. It had five major areas of discussion including:

[25]

Water and sanitation, energy, health and environment, agriculture and brodiversity and ecosystem. The Rio declaration was implemented in this Summit in 10 major chapters.

[66	What are the 3P's of environment?
100	Ans. The 3 P's of environment are population, poverty and pollution.
[67	
107	Ans. The action plan of Rio conference was enlisted in the form of Agenda 21,
	it had 40 chapters and was aimed at the sustainable development in the 21st
	century.
	EXERCISE
• A.	Essay type /Long Answer type :
[1]	
[2]	What is energy flow in an ecosystem 9 Why is it unidirectional? Discuss its various phases.
191	(Ans. 13.5)
[3]	What is an ecosystem? May we call aquarium as an ecosystem. ? Describe ecosystem of pond. (Ans. 13.3)
[4]	What do you mean by producers, consumers and decomposers in an ecosystem? What is the part played
• •	by them in an ecosystem? (Ans. 13.3)
[5]	What is meant by ecosystem? Give an idea of food pyramid and energy flow in an ecosystem.
[6]	(Ans. 13.5, 13.3) What is meant by ecosystem ? Explain energy flow with the help of examples.
lol	[J.E.E. 1984] (Ans. 13.3, 13.5)
[7]	What do you mean by the term consumer and producer? What is the relation between them? What is
	food chain? (Ans. 13.3, 13.3.2)
[8]	Define ecology? What are the components of ecosystem? (Ans. 13.3)
[9]	What is succession ? What are its different types? How secondary succession occurs in nature? (Ans. 13.2)
[10]	What do you understand by producer and consumer? What are their relationships? Write what will
	happen when there is disturbance in the balance of ecological environment (Ans. 13.3)
[11]	What is biogeochemical cycle? State its different types and describe each type. (Ans. 13.6)
[12]	What is Biosphere reserve? Describe it. (Ans. 13.7.1) Give a brief description of Sundarban Biosphere Reserve (Ans. 13.7.2)
[14]	What is pollution? How air and water are polluted? What are their preventive measure?
	(Ans. 13.14 Q-23; 13.8.3; 13.8.4)
[15]	How the environment is polluted? How pollution can be controlled?
[16]	(Tripura H.S. 1983) (Ans. 13.14 Q-24, 25) What do you mean by pollution? How environment is polluted? What are preventive measures for
1.01	water pollution? (Ans. 13.14 Q-23, 24; 13.8.4)
[17]	Discuss the source, harmful effects on man and preventive measures of air pollution (Ans. 13.8.3)
[18]	What is pollution? Mention the major causes of water pollution in our country. Discuss in brief the
	adverse effects of water pollution on human being and mention their control measures.
[19]	[Tripura H.S. 1997] (Ans. 13.14 Q-23; 13.8.4) What do you mean by noise pollution? Discuss the sources, harmful effects and controlling measures of
11	noise pollution. (Ans. 13.8.6)
[20]	What is pollution? Describe the causes and controlling measurs of air pollution.
1311	J.E.E. 1993l (Ans. 13.14 O-23 : 13.8.3)
[21]	(a) Name two very low-cost methods a common man can adopt to keep the river Ganga clean. (b) How can noise pollution be effectively controlled? [J.E.E. 1987] (Ans. 13.14 O-31: 13.8.6)
[22]	Give one cause and controlling measure of each of air pollution, water pollution and noise pollution.
	(IFF 1099) /Anc 12 9 2 : 12 9 4 : 12 9 6
[23]	What is noise pollution? What are its ill effects on humans? What measures are to be adopted to prevent
[24]	an ponution :
1-41	What is pollution? Describe briefly the different types of pollution and how they are affecting the biological world. (Ans. 13.8: 13.8.2: 13.8.3: 13.8.4: 13.8.5: 13.8.6: 13.8.7)
	(*************************************

Briefly discuss the following aspects of noise pollution: cause, measurement of pollution, bad effects

and preventive measures. (Ans. 13.8.6)

(Ans. 13.8; 13.8.2; 13.8.3; 13.8.4; 13.8.5, 13.8.6, 13.8.7)

[26]	(a) What are the side effects of sound pollution ? (b) Mention the effective measures to prevent sound
	pollution J.E.E. 1995 (Ans. 13.14 Q-37; 13.8.6) Name the sources of sound pollution Name some hygienic effects of sound pollution.
[27]	[J.E.E. 1996] (Ans. 13.14, Q-39, 38)
[28]	Briefly discuss the following aspects of water pollution—cause, bad effects and preventive measures (Ans. 13.8.4)
[29]	(a) Suggest two methods which can be adopted to keep the river Ganga clean (b) What is PAN? (c)
1	What do you mean by degradable and non-degradable pollutants? Give examples
	[J.E.E. 1997] (Ans. 13.14 Q-31, 28, 27) (a) What are different causes of sound pollution? (b) What are the hazards of sound pollution? (c) State
[30]	the important points of prevention as per Hon'ble High Court order in our state
	[J.E.E. 1998] (Ans. 13.14 Q-39, 40)
[31]	What is pollution? State the various causes of air-pollution and mention its control
	[Tripura H.S. 1998] (Ans. 13.14 Q-23; 13.8.3)
[32]	What is pollution? What are the causes of water pollution? Describe the effects of water pollution on human. (Ans. 13.14 Q-23; 13.8.4)
[3.3]	Write down the causes of air pollution. Describe the effects of air pollution in human.
[0]	(Ans. 13.8.3)
[34]	What are the major types of soil pollution? How it can be controlled? (Ans. 13.8.5)
[35]	What is radioactive pollution? Write its sources, adverse effects on man and preventive measures. (Ans. 13.8.7)
[36]	What are pollutants? Classify them. (Ans. 13.8.1)
[37]	Give a brief account of biomagnification and bioaccumulation (Ans. 13.8.8; 13.8.9)
[38]	Why are lead, cadrum and mercury harmful for human system? (Ans. 13.8.10)
39	Comment on ozone hole. (Ans. 13.9.1) Why is acid rain caused? What are its remedies? (Ans. 13.9.2)
[40]	Why is acid rain caused? What are its remedies? What is thermal pollution? How is it controlled? (Ans. 13.9.4)
[42]	How industries cause environmental pollution? (Ans. 13.8.3; 13.8.4; 13.8.5; 13.8.6; 13.8.7)
[43]	What is wetland? Why is its important? (Ans. 13.9.6)
[44]	What is meant by Green Bench? What are its major domain? State some of its major verdicts.
1.4.771	What is CPCB? What are its major duties and achievements? (Ans. 13.10.1)
[45]	Comment of Earth Summit of 1992 What is meant by Agenda 21 (Ans. 13.10.3)
[47]	What are the major declarations of Johannesburg Summit? What was the major rift observed in this
	summit? (Ans. 13.10.3)
• B S	hort Answer type :
[1]	What is food pyramid? (Ans. 13.1)
[2]	What is biosphere? (Ans. 13.1) What is ecosystem? [J.E.E. 1992] (Ans. 13.3)
[3]	What is ecosystem? What is the relation between producers and consumers? J.E.E. 1992 (Ans. 13.3)
[4]	What is food chain? [J.E.E. 1992] (Ans. 13.3.2)
[6]	State the role of decomposer in ecosystem. [J.E.E. 1985] (Ans. 13.3)
[7]	What is ectocrines? (Ans. 13.3) What is the nature of energy flow in ecosystem? [J.E.E. 1983] (Ans. 13.5)
[8]	What is the hattire of chergy has in consistent and the same 12 23
[9]	(Ans. 13.2)
[11]	Describe plant succession. (Ans. 13.2.1)
[12]	What is food web?
[13]	HOW does water cycle operate in nature .
[14]	What is meant by sedimentary cycle? What are the minimum criteria for a biosphere reserve? (Ans. 13.7.1) (Ans. 13.7.2)
[16]	Name the major flora and fauna of Sundarban Biosphere Reserve (Ans. 13.7.2)
[17]	What do you mean by primary pollutants and secondary pollutants? Give two examples of each
11/20	(Ans. 13.8.1)
[18]	What do you mean by natural pollution and anthropogenic pollution ? Give two examples of each. (Ans. 13.8.2)
[19]	How deforestation is related to pollution? (Ans. 13.8.3)
[20]	How the environment is polluted by agricultural activities? (Ans. 13.8.3; 13.8.4; 13.8.5)
{21}	How automobiles are related to pollution? (Ans. 13.8.3; 13.8.6)

[35] Write the full name of PAN.

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		(Ans. 13.14 Q-33; 13.8.3)
[22]	What is photochemical smog? How does it harm us?	(Ans. 13.8.6)
[23]	What are the effects of noise pollution?	(Ans. 13.8.4)
[24]	What are the measures to control water pollution.	[Tripura H.S. 1996] (Ans. 13.8.3)
[25]	State in brief the causes and remedies of air pollution.	(Ans. 13.8.3)
[26]	Name two air pollutants, their sources and effects on man.	[J.E.E. 2001] (Ans. 13.8)
[27]	Define pollution.	(Ans. 13.14 Q-52)
[28]	How biocides cause environmental pollution?	(Ans. 13.8.3)
[29]	What are brown air and grey air?	(Ans. 13.8.5)
[30]	What are the remedies of soil pollution? Explain bioaccumulation with a suitable example.	(Ans. 13.8.9)
[31]		(Ans. 13.8.10)
[32]	What is dislexia? What is Minamata disease?	(Ans. 13.8.10)
[33]	Comment on the Green House effect.	(Ans. 13.9)
[34]	State the various effects of ozone depletion.	(Ans. 13.9.1)
[35]	State damaging aspects of acid rain.	(Ans. 13.9.2)
[37]	What are BOD and COD?	(Ans. 13.9.3)
[38]	How is thermal pollution controlled ?	(Ans. 13.9.4)
[39]	What is wetland? How is it conserved?	(Ans. 13.9.6)
[40]	State the major environment protection acts.	(Ans. 13.10)
[41]	How is Green Bench functioning?	(Ans. 13.10.1)
[42]	What are the duties of SPCB?	(Ans. 13.10.2)
[43]	What is the importance of environmental summit?	(Ans. 13.10.3)
	Very Short Answer type :	
	What are biosphere and biomass? What will happen if the porduce	re are less than the consumers ?
[1]	What are biosphere and biomass: What will happen it the porduce	J.E.E. 1996] (Ans. 13.1, 13.3, 13.4)
	·	(Ans. 13.5)
[2]	What is the ten percent law?	(Ans. 13.4)
[3]	How many types of pyramids are there in an ecosystem? What is the source of energy flowing through the ecosystem.	(Ans. 13.5)
[4]	What is detritus food chain?	(Ans. 13.3.2)
[5]	Name the components of any ecosystem.	[J.E.E. 1983] (Ans. 13.3)
[6]	What is the primary component of any ecosystem?	(Ans. 13.3)
[7]	What is tertiary consumer?	(Ans. 13.3)
[9]	What is decomposer?	(Ans. 13.3)
[10]	What is grazing food chain?	(Ans. 13.3.2)
[11]	What is primary carnivore?	(Ans. 13.3.3)
[12]	What are the abiotic components of an ecosystem?	(Ans. 13.3)
[13]	What is sedimentary cycle?	(Ans. 13.6.1)
[14]	How was Biosphere Reserve launched?	(Ans. 13.7.1)
[15]	What is meant by manipulation zone?	(Ans. 13.7.1)
[16]	How did Sundarban derive its name? What is its total area?	(Ans. 13.7.2)
[17]	Name 2 weedicides.	(Ans. 13.8.5)
[18]	How is biomagnification demonstrated?	(Ans. 13.8.8)
[19]	What is phytochelatin ?	(Ans. 13.8.9)
[20]	What is meant by Itai-Itai disease?	(Ans. 13.8.10)
[21]	What is organic mercury?	(Ans. 13.8.10)
[22]	How CFC is harmful for the ozone layer?	(Ans. 13.9.1)
[23]	State the damaging espects of acid rain.	(Ans. 13.9.2)
[24]	What are BOD and COD?	(Ans. 13.9.3)
[25]	How is thermal pollution harmful ?	(Ans. 13.9.4)
[26]	State the damaging aspects of textile and leather industry.	(Ans. 13.9.5)
[27]	Why are photographic effluents and plastic effluents toxic to mank	
[28]	State some importances of wetland.	(Ans. 13.9.6)
[29]	Name some wild life protection act prior to independence.	(Ans. 13.10)
[30]	What are the major areas of Green Bench?	(Ans. 13.10.1)
[31]	State some achievements of CPCB.	(Ans. 13.10.2)
[32]	What are NAAQMC and WQMC?	(Ans. 13.10.2)
[33]	What is the importance of Rio-Summit?	(Ans. 13.10.3)
[34]	State the Johannesburg declaration.	(Ans. 13.10.3)

[J.E.E. 2002] (Ans. 13.14 Q-41)

D. Distinguish betwee:

- 27			(Ans. 13.13)
[1]	Food chain and food web.		,
[2]	Pyramid of number and pyramid of biomass.		(Ans. 13.10)
			(Ans, 13.5.1)
[3]	Photoplankton and Zooplankton.	20 20 20 111 =	(Ans 13.5.1)
[4]	Plankton and Benthos.	1 16/16 21/	(Ans. 13.5.1)
[5]	Biosphere and Biomass.	स्थान क्यां स्थापत	(Ans. 13.1; 13.4)
	Consumers and Producers.		(Ans. 13,3)
[6]	Cougnitiers said randerers. ACL 2006	न्ये पृथि । १७) ८	(Ans. 13.3)
[7]	Producers and Decomposers.	" ufil /sheur +"	(Ans. 13.6.1)
[8]	Nitrification and Denitrification.	4 4 2 4 4 1	
[9]	Fungicides and Pesticides.		(Ans. 13.8.2)
٠.		Section Section	(Ans. 13.7)
[10]	Green house effect and Green House gas.	Ay de English of Artificial Control of the Control	D/ 1 D 44 6 93
[11]	BOD and COD	the raine sed for pur ing the	4 317 4 317
[12]	C.P.C.B and S.P.C.B.	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	(Ans. 15.10.2)
	NAA OMC and WQMC		(Ant. 13.10.4)
[13]		to the management of the second	(Ans. 13.10.2)
[14]		A SECTION OF BUILDING	(Ans. 13.10,3)
[15]	Stockholm and Rio-Conference.	1996 Y	(Aus. 15.10,5)

. E. Write Short Notes on :

[1] Biosphere (Ans. 13.1) [2] Food pyramid. (Ans. 13.4) [3] Phytoplankton (Ans. 13.5) [4] Food Chain (Ans. 13.3.2) [5] Food web (Ans. 13.3.3) [6] Producer (Ans. 13.3) [7] Consumers (Ans. 13.3) [8] Decomposers (Ans. 13.3) [9] Pyramid of number (Ans. 13.4) [10] Pyramid of energy (Ans. 13.4) [11] Lindemann's data. (Ans. 13.5.1) [12] Plant succession. (Ans. 13.2.1) [13] Water cycle. (Ans. 13.6.1) [14] Sedimentary Cycle (Ans. 13.6.1) [15] Biosphere Reserve. (Ans. 13.7.1) [16] Sundarban Biosphere Reserve. (Ans. 13.7.2) [17] Biomagnification. (Ans. 13.8.8) [18] Bioaccumulation. (Ans. 13.8.9) [19] Lead toxicity. (Ans. 13.8.10) [20] Ozone depletion. (Ans. 13.9.1) [21] Thermal pollution. (Ans. 13.9.4) [22] Importance of Wetland. (Ans. 13 9.6) [23] Green Bench. (Ans. 13.10.1) [24] Pollution control Boards. (Ans. 13.10.2) [25] Farth Summit. (Ans. 13.10.3) [26] Johannesburg Conference. (Ans. 13.10.3) [27] Ill effects of noise pollution. (Ans. 13.8.6) [28] Causes of water pollution (Ans. 13.8.4).

• F. Choose the Correct Alternative:

- Phanerophytes grow well in tropical/temperate/polar regions.
- The word Ecosystem was coined by Haeckel/Tanslay/Odum. 121
- Aquarium is a natural/artificial ecosystem. 131
- Sulphur cycle is an example of sedimentary/gaseous/hydrologic cycle. [4]
- Azotobacter is a nitrifying/denitrifying/nitrogen fixing organism. 151
- Lead is most damaging for bone/blood/nerves/all. 161
- Itai Itai disease is caused by cadmium/mercury/lead. 171
- Minamata disease is caused by cadmium/lead/mercury. 8
- The central zone of a Biosphere Reserve is core zone/buffer zone/manipulation zone 91
- The component that exhibits biomagnification is DDT/heavy metals/both. 3.00
- The organism that denotes a particular pollution in a place is bioaccumulator/bioindicator/biomagnifier. (11)
- Phytochelatins mostly bind with heavy metals/drugs/pesticides. [12]
- The organism that can convert inorganic mercury to methyl mercury is Clostridium/Pseudomonas/both. [13]
- The component of CFC that causes ozone depletion is chlorine/fluorine/carbon. [14] The ozone layer is mostly present in the stratosphere/ionosphere/troposphere.
- [15]
- Increase in BOD of a water body is brought about by sewage/heavy metals/pesticide. [16]
- Wetland is most useful for biodiversity/oxygen supply/pisciculture/all. [17] The Environment Protection Act was introduced in 1974/1981/1986.
- 18
- The Green Bench was established in Calcutta High Court in 1998/1996/1994. [19]
- The CPCB was established in 1981/1979/1974. 1201
- The Man and Biosphere programme was intuated after the Rio/Stockholm/Nairobi conference. [21]
- Agend 21 was released in the Rio/Nairobi/Johannesburg conference. [22]

G. Fill in the Blanks:

	The term 'Ecology' was coined by
[2]	The Age and Area hypothesis was denoted by
131	Ecological Pyramids were denoted by in in in
[4]	The aquatic organisms with the power of locomotion is called
[5]	The linear food-predator relationship is called
131	When a group of organisms are replaced by another group or organism, it is called

	God as a definite area it is called species.
[7]	When a group of organisms remain confined to a definite area, it is called species. When a group of organisms remain confined to a definite area from where food is obtained.
[8]	
[9]	Plantage avente of nitrogen CVCR AIC
[10]	and eveles belong to sedimentary eyeres.
[11]	The outermost area in a Biosphere Reserve is
[12]	The Biosphere Reserve in West Bengal is the
[13]	Lungs are affected mainly by pollution.
[14]	Alimentary canal is affected mainly by pollution.
[15]	Noise pollution affects mainly the
[16]	Decibel is the unit for measuring sound
[17]	Two common air pollutants are and effluents. Water pollution may be caused by and effluents.
[18]	Water pollution may be caused byand
[19]	Electrostatic precipitators are used for purifying the
[20]	pollution causes early presbycusis.
[21]	Agents responsible for pollution are called The phenomenon of increase of a pollutant in a food chain is called
[22]	The phenomenon of increase of a pollutant in a look chain is
[23]	Acid rain causes cancer.
[24]	Stagnant water bodies are more prone to pollution.
[25]	helps in recharging of water into the soil. Industrial pollutants added to water increases the of water body.
[26]	industrial pollutants added to water increases the
[27]	Lead induces anaemia by blocking biosynthesis.
[28]	is more toxic than inorganic mercury to aquatic organisms.
[29]	and are two green house gases. The Act against biomedical waste was enforced from
[30]	SPCB categorized industries into,and categories.
[31]	SPCB categorized industries into
[32]	Agenda 21 had chapters.
[33]	The 2002 global summit was held at
• H.	Put ✓ mark on Yes/No:
[1]	Zooplanktons are benthonic in habit. Yes/No.
[2]	Ecosere forms the climax community. Yes/No.
[3]	Food chain is the actual representation of an ecosystem Yes/No.
[4]	Pyramid of number is inverted when the size of the producer is small Yes/No
[5]	Gross production is bigger than net production. Yes/No.
[6]	Carbon cycle is a sedimentary cycle. Yes/No.
[7]	Buxa-forest in West Bengal is a Biosphere Reserve. Yes/No.
[8]	The Buffer Zone II in a Biosphere Reserve contains a research station. Yes/No.
[9]	DDT exhibits bio-magnification. Yes/No.
[10]	Lead induces dislexia. Yes/No.
[11]	Cadmium caused the Minamata disease. Yes/No.
[12]	Sewage pollution increases BOD level. Yes/No.
[13]	Methyl mercury is more toxic than inorganic mercury. Yes/No.
[14]	
[15]	Wetland are useful waterways. Yes/No.
[16]	The ozone layer is maximum at the troposphere. Yes/No.
[17]	The EPA came into enforcement from 1986. Yes/No.
[18]	Plant hormones can act as weedicide. Yes/No.
[19]	Algae exhibit bioaccumulation in polluted areas. Yes/No.
[20]	
[21]	SPCB works independently from CPCB. Yes/No.
{22	
[23	
[24	Sulphur dioxide gas is a secondary air pollutant. Yes/No.
125	
126	
[27	
[28	
[29	
[30	A severe gas leak accident occured in Chemobyl of USSR. Yes/No

• 1. Match the following:

- [1] Parthenium
- [2] Sulphurous acid
- [3] Chlorine hydrochloride
- [4] Benzopyrine

- (a) Cancer of lungs.
- (b) Allergy.
- (c) Erosion of marble
- (d) Tooth decay.

Answer to Q No [F], [G], [H] and [I]

- [F] [1] tropical; [2] Tanslay; [3] artificial; [4] sedimentary; [5] nitrogen-fixing; [6] all; [7] cadmium; [8] mercury, [9] core zone; [10] both, [11] bioindicator; [12] heavy metals; [13] both; [14] chlorine; [15] stratosphere; [16] sewage; [17] all; [18] 1986, [19] 1996; [20] 1974; [21] Stockholm; [22] Rio.
- [G] [1] Earnst Haeckel; [2] Willis; [3] Charles Elton, 1927; [4] nekton; [5] food chain; [6] succession; [7] endemic; [8] habitat; [9] nitrification, denitrification, nitrogen fixation; [10] Sulphur, phosphorus; [11] Manipulation zone; [12] Sundarbans; [13] air; [14] water; [15] ears; [16] intensity; [17] smoke, dust; [18] industrial, domestic; [19] air; [20] Noise; [21] pollutants; [22] biomagnification; [23] stone; [24] thermal; [25] wetland; [26] COD; [27] haemoglobin; [28] Methyl mercury; [29] CO₂, SO₂; [30] 1998; [31] red, orange, green; [32] forty; [33] Johannesburg.
- [H] {1] No; [2] Yes; [3] No; [4] Yes; [5] Yes, [6] No; [7] No, [8] Yes; [9] Yes; [10] Yes; [11] No, [12] Yes; [13] Yes; [14] No; [15] No; [16] No; [17] Yes; [18] Yes; [19] Yes; [20] Yes; [21] No; [22] Yes, [23] Yes; [24] No; [25] No; [26] Yes; [27] Yes, [28] No; [29] Yes; [30] No.
- [1] [1] (b); [2] (c); [3] (d); [4] (a)

14

Applications of Biology

Topics Discussed: Biofertilizers, Pesticides and biological pest control benefits and hazards, Domestication of animals and plants and conservation of endangered species (with examples) Red Data Book, Green Data Book, Insects and their products. Scriculture, Apiculture, Lac-culture, Biotechnology and its Benefit, Cloning and transgenic microbes, plants and animals. Sperm and ova bank, Surrogate mother, Test-tube baby, DNA fingerprinting and its relation to forensic biology, Gene mapping, Cell & tissue culture, totipotency, micropropagation, role of phytohormones in agriculture, Biomedical engineering, FCG, EEG, Autoanalyser, USG, CT scan. X Ray, Fluoroscopy, Endoscopy. MRI, Laser therapy, Dializer, Pacemaker. Heart Lung Machine.

14.1. Biofertilizers

Definition: The organisms which increase the nutrient availability to crop plants either directly or through soil enrichment.

They are broadly of 3 types: bacteria, cyanobacteria and mycorrhizal fungi. Biofertilizer is quite different from manure and their differences are discussed below:

Diorettiizes to question and the second		
Manure	Biofertilizer	
(i) It is semi-decomposed organic matter added to the soil.	(i) They include macro-organisms, which increases the nutrient availability to crop plants.	
(ii) Manure helps in the maintenance of air, water in the soil.	(ii) It is essentially not connected with the maintenance of soil texture, through it may do the same activity.	
(iii) It provides different types of nutrients to crop plants. (iv) Manures may change soil texture.	 (iii) It only provides nitrogen and few other nutrients to crop plants. (iv) Biofertilizers do not change soil texture. 	
(v) Manures can be classified as farmyard manure, compost manure and green manure.	(v) Biofertilizers include bacteria cyanobacteria and mycorrhizal fungi.	

(a) Bacteria: The bacteria can be classified as free living nitrogen fixing bacteria, loosely associated nitrogen fixing bacteria and symbiotic nitrogen fixing bacteria.

(i) Free living nitrogen fixing bacteria: These bacteria grow freely in the soil and enrich the soil with nitrogen. They may be saprophytic like Azotobacter, Clostrudium Beijerinckia, photoautotrophic like Rhodopseudomonas and Chromatium. They can be very effective in reducing nitrogen fertilizer in the crop fields, as for e.g. Azotobacter can reduce the use of nitrogen fertilizer to the tune of 10-25 kg/ha in the paddy fields.

(ii) Loose association of nitrogen fixing bacteria: These bacteria grow in the rhizosphere of crop plants, they fix atmospheric nitrogen and a portion of it is transferred to the crop plant. This association is also called associative mutualism. Dobreiner (1975) showed an increase in the yield of maize crop due to the presence of the nitrogen

fixing bacteria Azospirillum lipoferum in the rhizosphere.

(iii) Symbiotic nitrogen fixing bacteria:

These bacteria form a symbiotic association with the root of higher plants. The most common amongst these organisms is Rhizobium, which grows in the root nodules of legume plants. These organisms include R. leguminosarum, R. lupini, R. trifolii, R. meliloti, R. phaseoli. They cannot fix nitrogen while growing in the scal as a free organism, but can only do that while in the nodule due to the presence of a pink-red pigment called leghaemoglobin, which removes oxygen from the site of nitrogenase and helps in nitrogen fixation. But these crops should be grown in nitrogen free soil, otherwise the nitrogen fixing ability of the bacteria is hampered. Presence of phosphorus stimulates nitrogen fixation. Dreyfus (1979) has shown that one legume plant Sesbania rostrata can extibit double symbiotic relationship with Rhizobium in the root nodule and Aerorhizobium caulinidans in the stem nodules, that enriches their protein content.

Other symbiotic nitrogen fixing bacteria include Frankia growing in the root nodule of Casuarina, Alnus, Rubus. Leaves of certain plants like Ardisia contain specialized cavities housing symbiotic nitrogen fixing bacteria like Xanthomonas, Mycobacterium and hence such leaves can enrich the nitrogen content of the soil.

(b) Cyanobacteria: The cyanobacteria can be of two types, i.e., it is either free

living or symbiotic in nature.

- (1) Free living nitrogen fixing cyanobacteria: These cyanobacteria or blue green algae grow freely in the soil. They include Nostoc, Anabaena, Tolypothrix, Cylindrospermum, Aulosira, Stigonema. They are photosynthetic in nature and can enrich the soil effectively with nitrogen. Aulosira fertilissima is widely used as a nitrogen fixer in the paddy fields all over India. (Aiyer et al, 1972). Cylindrospermum licheniformis is used in the sugarcane and maize fields, contributing 30-44% of fixed nitrogen to the crop plants. In fact it is estimated that a cyanobacterium can fix 20-30 Kg/ha of nitrogen and that is sufficient to meet the requirement of rice crop. According to Srinivasan, 1980, cyanobacteria has accounted for 100% saving of nitrogen fertilizers in Tamıl Nadu, only supplementation of phosphate and potassium is required.
- (ii) Symbiotic nitrogen fixing bacteria: The nitrogen fixing cyanobacteria can develop symbiotic association with liver worts, ferns and cycad roots. Azolla pinnata is an aquatic fern growing in the stagnant water of paddy fields, its leaf cavities contain a nitrogen fixing cyanobacteria called Anabaena azollae, which provides nitrogen to the rhizosphere of paddy plants. With the harvesting of the crop, the dried fern serves as a green manure, enriching the field for the next crop.

(c) Mycorrhizal fungi: These fungi grows symbiotically with the roots of higher plant. The mycorrhizae can either be ectomycorrhizae or endomycorrhizae.

(i) Ectomycorrhizae: These fungi are also called ectotrophic mycorrhizae, they mainly grow on the surface of the root and also in the outer cortex of plant roots like Quercus, Pinus, Eucalyptus. They help in absorption of water, solubilization of organic matter from humus, greater absorption of minerals (P, K, Ca) from the soil, production of antimicrobial substances in the rhizosphere and there by protecting the plant from pathogen.

(ii) Endomycorrhizae: They are also called endotrophic mycorrhizae, because they mainly grow within the intercellular space of cortical region of grasses, orchids producing a swollen area called vesicles or finely branched masses called arbuscles hence these fungi are also called vesicular arbuscular mycorrhizae. They help in the absorption of mineral nutrients (particularly phosphate), they release some growth promoting substances, which help in the vigorous growth of the plant roots.

14.2. Pesticides and Biological Pest Control

14.2.1. PESTICIDES:

The term pesticide in broader sense is denoting a killer of pests. The word insecticide literally means killer of insects. This term is derived from the Latin suffix, cida, or 'killer'. In addition to insecticides, other common pesticides are acaricides—killers of mite and tick, herbicides-killers of weed, fungicides-killers of fungus, and nematicides-killers of nematode. Other designations of pesticides have even more specific names, such as some insecticides may be called aphicides when used for aphids and termicides, when used for termites. These are all classed as economic poisons because the substances are used for controlling, preventing, destroying, repelling or mitigating any pest. In most instances, insecticides are chemicals. Most insecticides are nerve poisons.

14.2.2. HISTORICAL HIGHLIGHTS OF PEST CONTROL:

Agricultural pest problems are nearly as old as the beginnings of crop cultivation. The earliest record of pest control seems to be the use of sulfur by ancient people near about 2500 B.C. The Chinese had discovered the use of soap to control pests during the middle ages. By the late 1600s, tobacco infusions and insecticides from other herbs, as well as arsenic, were commonly used. There was a rapid development of insecticides application in the late eighteenth century and early ninteenth century.

The insecticide era roughly from 1959 to 1962 dates within this period, tremendous development of insecticides had taken place. The discovery of the insecticidal properties of DDT marked the beginning of this era. During World War II, DDT was used primarily against mosquito, flea and louse. DDT application saved thousands of lives that would have been killed by malaria and typhus. Indeed, DDT had much impact on human health. After World War, DDT had phenomenal successes against agricultural pests. During this period, other effective insecticides were developed from the chlorination of hydrocarbons. The trend in pest control was towards the development of new and even more effective inscecticides.

14.2.3. PEST CONTROL:

It is the application of technology, in the context of biological knowledge, to achieve a satisfactory reduction of pest numbers or effects. The technological aspect includes insecticides and also the equipments, which are used to apply insecticides. Biological knowledge allow us to know when, and how to apply the technology. Biological knowledge necessary for pest control includes these facts: (i) whether the species is tropical or sub-tropical in origin and survives only indoor or outdoor; (ii) whether the pest prefers warm/cold, dark/light, or humid/dry environments; (iii) whether the pest feeds widely on all sorts of plant and animal products; (iv) incubation period of eggs of the pest etc.

Insecticides and other pesticides are some of the most important chemicals used for the well being of men. They are indispensable in maintaining high levels of health, nutrition, and surroundings. In agricultural production, pesticides are a regular component of most systems, and their development has given rise to entirely new

ways of growing crops. Moreover, the quantity and quality of our food and fibre production could not be maintained without substantial use of pesticide.

Insecticides are particular kinds of pesticides for killing insects and other invertebrates. They account for about 11% of the pesticide quantity used on major field and forage crops, but they represent more than 22% of that used for home and garden purposes.

Increasing insecticide use since World War II is the result of several advantages these chemicals have, over other techniques for insect control. They can treat an insect problem while it is in progress, reducing pest numbers to insignificant levels. Action of insecticide is rapid and usually the insecticide takes effect within hours; so that the problem is removed within a few days. Insecticides are also economical compared with many other pest management tactics. Application of insecticides can be done easily. Persons with minimum training can apply the insecticides effectively.

14.2.4. CLASSIFICATION OF INSECTICIDES:

Insecticides are classified in several ways-

- (i) According to the toxic effect on the site of insect pest,
- (ii) According to nature and source of insecticides,
- (iii) According to chemical make-up of insecticides.
- (a) According to the toxic effect on the site of insect pest:

Insecticides are grouped into three headings, such as stomach poisons, contact poisons and fumigants.

(i) Stomach poisons: This type of insecticide enters the insect's body through the gastro-intestinal tract after being eaten and the effect is fatal. This type of insecticides is the oldest, but still few stomach poisons are used even today, such as boric acid. This is used against cockroaches and other crawling insects in the household. e.g.: Pyrroles.

Systemic insecticides have also been considered as true stomach poisons. Systemics are modern insecticides, which also act through the gut of the pests. After application of systemics, they are translocated within the body of plants and animals. Insect pests feeding on the protected host comes in contact with the insecticide through the gut and susceptible individuals are killed. Piercing and sucking type of insect pests are killed by systemic insecticide in plants. In livestock, systemic intecticides are used against internal parasites, such as cattle grubs of Hypoderma sp.

(ii) Contact poisons: It is the major group of modern insecticides. These insecticides generally enter the body when the insects walk or crawl over a treated surface. The insecticide is absorbed through the body wall. If the treated surface is a food source of insect like a leaf or blossom, then the insecticide enter the digestive tract of the insect, from where it is absorbed. Still, the primary entry site of contact poisons is from the environment and through the body wall.

e.g. Pyridaben

(iii) Fumigants are contact insecticides, whose contact site is tracheal system of the insect. Fumigants are highly volatile pesticides and become gases above 5°C temperature. These insecticides are applied to enclosures and to soil. Fumigants after entering to tracheal system are circulated inside the body of the insect and subsequently absorbed by the body tissues; ultimately the insects are killed. Fumigants have high penetrating ability and kill all stages of insects in enclosures including their eggs in greenhouses, homes, warehouses and package products of beans, grains and dried fruits.

Fumigants are also used against soil insects, nematodes and pathogenic microorganisms. Thus the fumigants are used for the destruction of pests in confined spaces. Examples of fumigants—Hydrocyanic acid gas, Carbon disulphide, Methyl bromide etc.

(b) According to nature and source of insecticides:

These are morganic and organic. Most modern insecticides are organic which contains carbon atom. Organic insecticides are further subdivided into natural and synthetic. Natural insecticides are produced by refining natural substances, such as botanical insecticides (derived from plants) and mineral oils (refining petroleum). Botanical insecticides have wide range of use; but mineral oils are used for suppression of fruit-tree insects and mosquito larvae. The most insecticides now a days are synthetics.

(c) According to chemical makeup of insecticides:

Insecticides are grouped on the basis of their chemical makeup. Several classes of compounds are designated according to their active ingredients which are responsible for the toxic effect. There are three major classes are pyrethroids, carbamates and organophosphates. Pyrethroids have certain advantages. This group of insecticides are highly toxic to insects and quickly affect on insect pests. Carbamates have wide application in agriculture. This group of insecticides is widely used in home, lawns and gardens. It has been also used for suppression of nematodes, corn rootworms and other soil pests. Organophosphates are the most widely used to day. This group is used safely against garden and household pests. It is commonly used for human louse. This group is effectively used for aphids, leafhoppers and piercing & sucking insects. It is also effective contact poison against mites.

14.2.5. HAZARDS OF PESTICIDES:

Pesticides increase the yield of crops but the indiscriminate use of pesticides invite the pest problems in a severe form and total devastation of crops been noticed. Improper use of pesticides creates serious problems, such as air and water pollution, health hazards, physical and physiological changes in the soil, detrimental effects on beneficial insects—predators, parasitoids, honey bees, destruction of natural balance and ecological cycles, development of resistant pests etc.

Fumigants like hydrocyanic acid gas or methyl bromide etc., are toxic to man, animals and plants. The greatest hazards of using fumigants are inflammability of the gas and accidental poisoning of man. Nematicides (fumigant to kill nematodes) are broadly toxic. In addition to nematodes, nematicides kill a range of soil organisms and their total effect is greater than the killing of nematodes alone. Nematicides also kill the nitrifying bacteria of the soil.

Disadvantages of application of mineral oils (insecticides) are as follows—(i) Phytotoxicity (toxic effect to plant), (ii) Instability during storage, (iii) Ineffectiveness against certain pests. During rains and wind, the residues of pesticides are quickly washed off from surfaces and carried away in runoff. As a result, the toxicity of insecticides can cause destruction of fish and wildlife populations in surrounding areas.

Health hazards of Man: Hazard is the danger or injury that will occur to man when he comes in contact with pesticides. The degree of hazard depends on the toxicity of the pesticides and the chance of exposure to the toxic amounts of the product. Thus pesticide causes two types of human poisoning, such as *Acute poisoning* and *Chronic poisoning*.

(a) Acute poisoning: This type of poisoning occurs to persons who are directly

involved in the manufacture of pesticides and application of pesticides to agriculture field. Acute poisonings also occur among non-professionals, such as in case of accidents, ignorance, suicide or crime. Acute poisoning causes illness or death from a single dose

of exposure.

(b) Chronic poisoning: This type of poisoning occurs from long-time exposure to low levels of toxicants. Chronic poisoning reveals only after several weeks of exposure, due to the widespread use of pesticide (DDT) for many years. DDT related compounds accumulated in animals that fed on residue laden plants. Consequently, there is high residues of pesticide in the milk fat of dairy cows. Ultimately, men ingest pesticide through milk. The main worry is that, food contains residues of pesticide which is consumed by men and repeated consumption of this type of milk can cause sickness or death to man. Thus the toxic residues in foods and on plants cause hazards to man.

Animals fed with sublethal doses of pesticides have shown several types of maladies. Most dangerous effects are given here—(1) Carsinogenic i.e., it can cause cancer; (ii) Mutagenic i.e., genetic change to future generations and (iii) Teratogenic i.e., defects in the offsprings of exposed pregnant females.

Hence the toxicity of pesticides is established by feeding (oral), skin application (dermal) and inhalation (respiratory). Lungs and other parts of the respiratory system are better absorbent of pesticides than skin.

Resistance of pests to pesticides:

Resistance to pesticides has also been observed in many species of insects, mites and rats. Resistance to pesticides has developed not only in house fly and mosquito but also in aphid, cabbage root fly, onion fly, carrot fly and soil pests. The possible means by which this resistance is achieved by pests are given below:

(1) The behaviour of insects is changed so that it avoids contact with insecticide. (2) Insecticide fails to reach the site of action (3) The poison of pesticide reaches the site of action, but it is detoxified by some metabolic process.

Toxic residues in Soils:

After application of more persistent types of pesticides, such as organochlorine or organobromine compounds to plants or soils, residues may persist in the soil for months or years together and accumulate there, by successive applications. This increasing concentration damages the root systems of sensative plants; the toxic residues can also cause off flavours of harvested product and small amount of that is being absorbed by plants, which are later consumed by man or domestic animals. Persistence of toxic residue is modifying soil texture, pH, moisture, temperature, microbial activity etc.

Hazards to Wildlife:

Increasing use of pesticides cause adverse effects on wildlife. Pesticide which is used to kill apids in sugarbeet causes the deaths of many birds specially pheasants and patridges. There was widespread use of insecticides like aldrin, dieldrin for the seed treatment of wheat to control wheat bulb fly.

The treated grain was often taken by birds; as a consequence of which there was death of large number of birds. Thus there was an alarming increase of deaths of grain eating birds. Sometimes treated grains are scattered in the field to kill pigeons. If only pigeons had been killed, there would have been less concern; but game birds and other desirable species are also killed. These contaminated birds were eaten by predator mammals and birds such as falcon and Montagu harrier.

The possible accumulation of pesticides in the fatty tissues of animals and their progressive increase of concentration in the food chain has given rise to much concern amongst naturalists. Failure of some predatory birds to breed successfully has been claimed to be caused by pesticides. It cannot be denied that pesticides are toxic to fishes, birds and mammals, and also to many invertebrates. Hence pesticides kill wild life

14.2.6. BIOLOGICAL PEST CONTROL:

Biological control may be defined as the action of living organisms (predators, parasitoids and pathogens) in maintaining a reduction in a pest's concentration. In short we can say that the biological control is the use of enemies, that is, predators, parasites, fungi, protozoa, bacteria and viruses to control a pest species. It is now realized that biological control is living weapon over chemical control. Biological control is a modern method of pest control, which is adopted at global level. Biological control differs from natural control in that, the latter may involve agents (weather, food) other than natural enemies. In the 4th century, Chinese discovered the use of natural enemies to control insect pests, such as they placed ants on citrus to reduce pest infestations. It was not until 1888, that biological control became firmly established as a significant method.

14.2.7. AGENTS OF BIOLOGICAL CONTROL:

Most species of insects are preyed upon or serve as hosts for other living organisms. These diverse natural enemies of insects include vertebrates, nematodes, microorganisms and perhaps most important, the insect themselves. Natural enemies may function as predators, parasites or pathogens.

- (a) **Predators**—They are free-living organisms that feed on other animals *i.e.*, prey. Predators may attack prey both as immatures and adults. Major predators of insects are mentioned here, such as birds, fishes, amphibians (toads and frogs), reptiles (lizards and snakes), mammals (bats and rodents) and arthropods (insects, mites and spiders). The most *important predators in biological control have been insects* and mites. Insect predators are **monophagous**, **oligophagous** and **polyphagous**. Insect predators which feed on a single species are known as monophagous; example vedalia beetle. Insect predators which feed on few species are known as oligophagous. Predators tend to feed on a wide range of prey and this group of predators is considered as polyphagous. Polyphagous predators can survive by shifting to alternate prey, when densities of pest species are low.
- (b) Parasites and Parasitoids—A parasite is an animal that lives on or within its host. The parasites feed on its hosts. As a result, the host becomes weak or dead. Parasites with the greatest impact on insect pest populains are insects and nematodes (worm). Insects that parasitize other insects are called parasitoids. A parasitoid is parasitic in its immature stage but is free living in the adults. Parasitoids kill their hosts. These natural enemies have been used more frequently in biological control than any other agents.

Nematode-based biological pesticides are used in horticultural and agricultural fields. This is also applied against mushrooms, berries, citrus etc. Even this type of biological pesticides is used against root maggots, mosquito larvae and soil insects. Parasites and

parasitoids have been used more frequently than predators in an attempt to enforce biological control.

(c) Pathogenic Microorganisms-

Insects are also affected by diseases just like men and other animals. Thus insect pest populations are often influenced by epidemic diseases. Insect diseases and their symptoms have been recognized by the Chinese as far back as 2700 B.C. in relation to honey bee and silkworm. The idea of using a microorganism to control a pest dates back to eighteenth century. To day, the science of insect pathology is contributing significantly to the biological control of insect pests.

The major micro-organisms which are causing diseases in insect pests are bacteria, viruses, protozoans, fungi etc. They are causing diseases that kill insects outright or

growth becomes slow, resproductive function is reduced.

Microbial insecticides are biological preparations that are sprayed in ways similar to those of chemical insecticides. The micro-organisms which are widely used as microbial insecticides are bacteria; but viruses and fungi are also used to a lesser extent.

Bacteria: Among the bacteria, genus *Bacillus* is the most effective against many pest species. The Bacillus group causes diseases in the beetles, moths and mosquitoes. The spores of some bacillus germinate and then penetrate the insect's gut and ultimately transform their blood milky or the spore of some other *Bacillus* causes gut paralysis. Death follows soon afterward. *Bacillus* is also used against some crops, cotton, maize, forests, potatoes, stored grain, tree fruits and tobacco.

Fungi: Some fungi are creating epidemic disease in insect pests. Thus they are also regulating the insect pest population. Generally spore of fungus attaches to the cuticle of insect pest, then the spore germinates and penetrates the body wall. In the body cavity of insect pest, the fungus spreads in the haemocoel and ultimately death occurs. Fungi have been used as microbial insecticide with much success in various parts of world. They are used against aphids, thrips, mealy-bugs and beetles.

14.2.8. DISADVANTAGES OF BIOLOGICAL PEST CONTROL

Although there have been some outstanding successes through biological control but its potential has not been fully developed for most crops. Hence there are some disadvantages which are given below.

(i) Polyphagous predators does not always suppress a growing pest population.

(ii) Pathogenic micro-organisms like protozoa and rickettsiae are not used extensively as microbial insecticides due to their slowness to kill insects, if they kill at all.

(iii) In case of hyper-parasitism, the original parasite of the pest *i.e.*, primary parasites are also not beneficial to biological control, when they parasitize insect predators.

(iv) The most important disadvantages of parasitoids in biological control are: host searching capacity may be highly reduced by weather and other factors; only the female searches the host and often the best searchers lay few eggs.

(v) To be effective, the parasitoid life cycle must coincide closely with that of its host before establishment and suppression can occur. Sometimes this synchronization may be upset by environmental conditions, thus the parasitoid fails to reduce host numbers significantly.

(vi) Viruses have not been widely developed for insect pest control due to its cost, slow activity and narrow killing spectrum.

14.3. Domestication of Animals and Plants

Man has brought the few kinds of other organisms under domestication or cultivation. As a result, the present numbers of people on the world depend on a small group of cereals, specially rice, wheat and maize. These cereals are produced high yield of food, they are easily transported and stored, large number of people are directly engaged in food producing activities. This has ultimately accounted for the development of cities. On the other hand the tubers like potato and others, though give an equally high food yield but are more difficult to be stored and transported; probably because of these tubers and tuber like substances have never served as a basis for city formation. In the ancient civilization man had domesticated few animals which are neither utilized as food nor as a source of power. Hence large-scale domestication of animal is not a necessary prerequisite for the development of civilization.

Cultivated plants and domesticated animals are together known as cultigens. The mutual interdependence between man and cultigens has developed through few thousand of years. This has happened due to cultural modification of man and biological modification of cultigens. Man has to learn agriculture and the learning is transmitted from generation to generation. Domesticated animals and plants, on the other hand, have become biologically very different from their wild ancestors.

14.3.1. MAN'S RELATION WITH OTHER ORGANISMS:

In the biological community, the primitive man survived primarily as a predator. But he was not exclusively a predator as because he also ate fruits, nuts and tubers as supplementary food. They developed social organization as well as they were using tools. Thus tools and group habits of man have given him a large extent of protection from other predators like lion and other carnivores. However his social organisation failed to protect him from parasitism. Some of the parasites, such as intestinal helminths, the malarial parasite and body louse took shelter in early man. These are the evidences to show that parasitism has also evolved right along with man. Hence man was predator, prey and host of parasites and also a collector of fruits, nuts and insect grubs. He also knew the method of collection of honey from bee hive. Subsequently, man had undoubtedly entered into a far wider variety of relations with other members of the biotic community than any other animals.

These relationships multiplied as man learnt to interfere more drastically with the biotic community. One of the first things he did was to build shelters. By building a crude sort of shelter in an environment, human invited a wide variety of animals, who quickly moved in to share the shelter, such as cockroaches, scorpions, lizards and rats. These men's uninvited guests are known as human inquilines.

Man deliberately propagates and encourages some animals and plants. These cultigens are now the most important of man's biological relationships. Many primitive men kept tamed animals around their settlements, which were captured individually from the wild environment. These animals were kept either for amusement or affection and were regarded as pets. Man's relationship with animals and plants can thus be separated into the following groups of organisms, such as (i) his prey (ii) his predators

(iii) his parasites (iv) his objects of collection (v) the inquilines (vi) the cultigens and (vii) the pets. Our interest is primarily on the cultigens. So we will examine man's relationship with the cultigens.

14.3.2. ORIGIN OF CULTIGENS (Domesticated animals and Cultivated plants):

We do not know exactly how man first discovered the value of domesticating animals and cultivating plants. Most probably we can understand from the nature of man and the evolution of his culture. Modern man's relations with the rest of the natural world depend largely on this man-cultigen relationship. How and when most of our important animals and plants were domesticated are still matters of controversy. For example, dog is generally considered to be the oldest of the domesticates. When and where the dog was first domesticated are still matters of controversy. Some says it represents a mixture of several wild species. The domesticated dog can be hybridized with many kinds of wild species in different parts of the world. Man and dog gradually complemented each other in a better way, since the dog has a much keener sense of smell and hearing, and man has better sight and better ability in solving problms. Thus they learnt to hunt together more efficiently than what they could do alone. However, we still depend on the cultigens that were brought under control in the dim twilight of prehistory. Perhaps prehistoric man had thoroughly ransacked the living world, as a result all useful cultigens were discovered. Thus we realize that man has not domesticated any important animal or plant within historic time. Minor exceptions to this are such animal as fruit fly (Drosophila) and some of the microbes such as the mould, that produces penicillin and few plants like rubber and quinine trees.

Within historic times there has been a vast exchange of cultigens (domesticated animals and plants) among people living in different parts of the world. Both biological and cultural factors must be considered in explaining cultigen distribution. The spread of potatoes and maize in the old world can only be explained in terms of both kinds of factors, which are favourable soil and climate as well as cultural acceptance. This exchange of cultigens can be more accurately traced than their origins.

The first cultivation and domestication probably took place in South-east Asian countries. It seems to be the original home of such household animals as pig, fowl, duck, goose and perhaps dog and other cultigens like bananas etc. South-west Asia appears to be the home of an entirely different set of cultigens, such as wheat, oats and barley and the grazing mammals. Native to tropical America are maize (corn), several vegetatively propagated sources of starch and a variety of vegetables and fruits. In both hemispheres fibre plants were also important among the early cultigens. The Americans domesticated few animals, such as Llama, alpaca, guineapig and several others.

14.3.3.THE MODIFICATION OF CULTIGENS:

Cultivated plants and domesticated animals of prehistoric times have been considerably modified in the course of their association with man. Many of them have become completely dependent on man and they are unable to live and propagate without the help of man. We can call them as 'obligate cultigens', such as maize (corn). The plant maize is completely helpless without man. Man takes initiative to husk the ears,

separate the seeds and then plant the seeds of maize. Maize failed to reproduce by itself even in a completely open habitat with no competition from other plants. On the other hand it has also been observed that the ancient civilization of the middle America could not have developed and maintained themselves without this maize. Thus manmaize close relationship has developed in tropical America. The food-producing man is biologically identical with food-collecting man, but the biological nature of cultigens has altered markedly.

How the nature of cultigens has modified? Wheat, maize, cotton and their wild relatives have been extensively studied with respect to their genetic constitution. The major objective of the study is to reconstruct the biological histories of the cultigens. Mutations which have no survival value in nature will persist and spread within the populations; these mutations might be favoured under man's care. Thus the genetic variability of cultivated population increased. Hybridization between cultigens and wild species may occur purposefully or accidentaly. As a result, there is further increase in the diversity of the gene pool.

Man has played very important role in guiding the evolution of his cultigens. We can see very clearly that the process of artificial selection is very effective in developing new breeds; thus the old ones are changing in the modern period. But it is difficult to assess the effectiveness of selection in the early stages of agriculture. Primitive people often seem to exercise a sort of negative selection *i.e.*, eating more desirable materials and using less desirable ones for reproduction.

One can imagine that the primitive man might have accidentally discovered the food value of these popped kernels of maize and thus led them to bring the plant into cultivation. Once cultivated, the whole complicated sequence of genetic events that led to modern maize (Corn) became explicable.

There is evidence that the wheats were first eaten by primitive man as perched grains and subsequently people used them as gruel and baking of bread came later. Changes in the biological nature of the plants and cultural ways of using them came slowly after cultivation had started. In the case of domesticated animals, their first significance may have been magical or religious rather than utilitarian. But whatever may be the beginning, man and his cultigens are now in close relationship and enjoy a mutally dependent partnership. This partnership is maintained by the process of agriculture.

14.4. Conservation of Endangered Species

The wild species means any living organisms (animals, plants and microorganisms) that are existing in its natural habitat but it excludes the domesticated animals and cultivated plants.

India is really a rich country with regard to her flora and fauna. Varieties of wild plants, animals and birds are still available in the jungle of the different parts of India. The lion, the tiger, the elephent, the rhino, the musk deer, the snow leopard, the wild buffalo, the wild ass and varieties of birds along with varieties of plants are still existing in India. All these wild animals and plants constitute a treasure of our country. But due to various reasons all these animals and plants are facing a great danger of extinction. Now the scientists in India as well as in other countries become conscious about the importance of wild animals and plants and they are now trying to protect and preserve

the animals and plants specially the endangered species. So conservation of wild animals is equally important as that of plants in the forests.

14.4.1. DEFINITION OF ENDANGERED SPECIES:

A species is endangered when it is facing a very high risk of extinction in the wild in the near future.

14.4.2. CAUSES OF RAPID DECLINE OF WILD SPECIES:

Many of the wild species both animals and plants have already been extinct and some are in danger and threatened to be extinct due to various reasons. *These threatened species are known as endangered animals and plants*. Some of the major reasons of declining of wild species are mentioned below.



Fig. 14.1: Showing the reckless killing of tigers and leopards by hunters during 19th century.

- (i) **Hunting** with fire-arm is one of the main cause of large scale destruction of the wildlife. This is done for food, pleasure and safety.
- (ii) Habitat destruction is the serious threat to wildlife. Due to population explosion, natural habitats are being converted to human settlements. Moreover, dams, reservoirs, grazing grounds and land for cultivation become necessary for the increase of human population. Environmental pollution and deforestation have also resulted in the destruction of natural habitats. All these factors are causing rapid decline of wild species.
- (iii) Introduction of exotic species has affected many native species. Along with new factors have also imposed on native species; new factors are the space, predation, destruction of habitats and transmission of diseases. As for examples—when goats, rabbits etc., are introduced in some islands of Indian Ocean, they are destroying the habitats of several plants, reptiles and birds. A fungus from China introduced to the America has devastated the American chestnut tree.
- (iv) Unscientific use of forest and marine as well as fresh water is also a serious threat to the aquatic animals and forest plants. Over-fishing from ocean and fresh water is causing serious threat to the marine as well as fresh water living resources. Many

species of whales, turtles, fishes and molluscs are on the verge of extinction. These are

used in food industry.

(v) International trade—There is a heavy demand of rare commodities from animals of wild origin in the international market such as fur, leather products etc. So wild-life is mercilesly exploited mainly from the developing countries. Thus many of the wild life become threatened species. Moreover, use of a wide range of animal and plant products for cosmetics, perfumes, pharmaceuticals etc., poses some other danger for wild species.

14.4.3. IMPORTANCE OF CONSERVATION OF THREATENED SPECIES:

The conservation of threatened species is very important for the following reasons.

- [1] Biological importance: The followings are the biological importance for the conservation of wild animals.
- (a) For balance in nature: The wild animals are the integral part of nature. The wild-life is maintaining the ecosystem of nature through the balance of polulation and food chains. Thus the wild animals are keeping the natural cycles. The animals that are existing in nature are preserving the environment as a self sustaining system.
- (b) For breeding programmes: The importance of wild-life lies in the breeding programmes in animal husbandry and agriculture. The animal and plant breeders are producing new varieties that are of high quality as well as disease resistant. For development, of such varieties a very wide range of animals and plants have to be screened and selected. Animal and plant breeders have been constantly examining the wild relatives of animals and plants for the presence of useful genes, which can be introduced in breeding programmes. The production of high quality hybrids with disease resistant live stock connot be continued without the wild relatives.
- (c) For evolutionary continuity: The diversity of organisms that we find today are the products of natural evolution. As we have no power to replace a lost species so it will be unwise to destruct the species. Moreover we have the responsibility to conserve the living organisms of great diversity for our progenies.

(d) For pollination: Birds are doing immense benefit as pollinating agents. They are also helping in dispersal of fruits and seeds, also act as scavengers as well as harmful

insect-eaters.

- [2] Economic importance: In addition to the biological importance, wild animals and plants are also regarded as a wealth of a nation. If this wealth of wild species is carefully conserved and properly used, economic benefit can be regained. Economic benefits are mentioned below.
- (a) From exporting: Through proper exploitation, a country can earn foreign currency by exporting the products of wild animals after their death, such as skin, horn
- (b) From tourism: Tourists from all over the world are not only coming to a country to visit the historical places but also they show keen interest about the wild animals and plants. If magnificent wild animals and plants of a country are conserved and properly maintained, it will be a source of great revenue.
 - (c) From zoo-gardens, museums and botanical garden: The people are getting

opportunity to observe the life specimens of wide diversities of wild animals in the zoological garden. So in well collected zoo-gardens, large number of tourists are attracted. Enriched museums (dead and preserved animals of the ancient times) and botanical gardens also attract the foreigner as well as local tourists. These centres are also a great source of revenue in addition to the academic value.

[3] Aesthetic value: The sweet song as well as the attractive colour of birds inspired the poets and also give pleasure to the people. Mythological stories in most cases are

based on wild animals, that help to raise the consciousness of man.

HOW WILD SPECIES DISTURB THE NATURAL BALANCE?

Animals are heterotrophic organisms, so for food they are depended either on plants or on other herbivorous animals. If one of the heterotrophic organisms of a food chain decreases, the other will flourish, as a result the natural food chain will be disturbed and cause harmful effects to the human society. As for example, in the natural heterotrophic food chain if the number of carnivores, such as lions or tigers or leopards are being decreased by hunting or other ways, the deer or other herbivores will flourish, as a result these huge number of herbivores will be attracted to crops and vegetables in the cultivating field surrounding the forest areas. On the other hand, if the number of carnivores like tigers, leopards etc., of a forest is increased, they will hunt for herbivores and ultimately they will infiltrate the human locality in search of food and kill the man and domestic animals. So increase or decrease of primary or secondary consumers will disturb the food-chain in nature and cause damage to the crops and vegetables or man and domestic animals.

If the birds in the nature are killed recklessly, pollination of the green vegetation will be disturbed, as a result the vegetation and crops will be decresed. This causes imbalance in nature.

If the random killing of wild animals continue, the balance of O, and CO, of the atmosphere will be disturbed, then the very existence of man on earth will be in great danger.

14.4.4. METHODS OF CONSERVATION OF ENDANGERED SPECIES

In the early part of the 20th. century, naturalists of the various countries realised the importance of conservation of wild species. Hence scientists of the world have developed a comprehensive world conservation strategy for the proper use of resources.

Conservation strategies: Some of the strategies are given here—(i) All efforts should be given for preservation of species specially that are endangered. (ii) There must be good planning and management of land and water uses; so that we can prevent the extinction of wild species. (iii) Different varieties of food crops, timber trees, livestock etc. and their wild relatives should be preserved and special priority should be given to threatened species. (iv) Economically valuable as well as useful plants and animals are to be preserved in the protected areas. (v) Habitats of the wild species, specially the endangered species should be protected. (vi) Utilization of living resources is to be kept at a sustainable level. (vii) Commodities of wild origin in the international trade are to be regulated by appropriate law.

For this purpose, in 1948 they formed 'International Union for Consertvation of

Nature and Natural Revources' (IUCN). Scientists subsequently also realised that financial help as well as expert opinion in relation to the conservation of wild-life may be needed for the developed and under developing countries. So in 1961 they established 'World Wild-life Fund' (WWF) for the above benefit.

Accordingly Government of India also set up 'Indian Board of wild-life' in 1952. The aim of this board is to render advice with regard to the wild-life conservation in our country. Some measures have been taken to protect and conserve the endangered species in our country by the 'Indian Board of Wild-life' as well as 'Wild-life Board' in the states. These measures are given below.

[1] Promulgation of law: India as well as other countries promulgated the laws about the protection of wild-life animals. Aim of the laws is to prohibit the killing of wild animals specially the endangered animals like tiger, rhinos, lion, snow leopards,

clephants etc.

[2] Protected areas: The feeding, breeding, rearing and resting areas of wild animals, which are economically valuable and useful are to be preserved in the protected areas. For this purpose, the Government of India introduced the Wild-life protection act in 1972. Under this act some forests can be converted as National Park, Sanctuary or Reserve forest for the conservation of useful endangered animals.

- (a) National Park: National park is a vast area which is strictly reserved for the wild species. In the national park forestry, cultivation, grazing and hunting of animals are strictly prohibited. Even the natural and historical objects are to be preserved. In India so far 66 national parks have been established, such as Corbett National Park in Uttar Pradesh, Kanha National Park in Madhya Pradesh, Hazaribagh National Park in Bihar etc.
- (b) Sanctuary: A forest can be declared as a sanctuary only to conserve the animals. In the sanctuary hunting, killing or capturing of wild animals are not permitted. But without disturbing the life of wild animals, collection of forest products and timber in a limited quantity may be allowed. In India there are 368 sanctuaries, such as Jaldapara sanctuary in West Bengal, Kaziranga sanctuary in Assam, Bharatpur bird sanctuary in Rajasthan, Dachigam sanctuary in Kashmir etc.
- (c) Reserve forest: Any forest where number of wild animals are rapidly decreasing due to reckless killing by hunters, poachers etc., can be declared as a reserve forest for protection and conservation of wild animals, such as Garumara Reserve Forest in West Bengal, Bandipur Reserve Forest in Karnataka, Gir Forest in Guirat etc.
- [3] To develop mass consciousness: Vast number of people of our country is not aware about the importance of wild animals and plants. Hence for the development of consciousness of those people, cinema shows about the wild-life including the necessity of their conservation are to be arranged frequently in far and near places specially in towns and villages. Thus the people may learn about the importance of conservation. Cinema shows about endangered species are also to be arranged in each and every schools and colleges, so that the students may have the opportunity to develop love and affection towards the wild animals and plants. People are to be requested to visit the zoo-gardens and botanical garden for acquentance with the living world so that they can educate themselves in addition to pleasure and enjoyment.

PROJECTS FOR CONSERVATION OF ENDANGERED SPECIES:

In India, some projects have been sanctioned to conserve properly the endangered animals (tigers, rhinos, lion, crocodiles, some varieties of deer etc.) which are distributed in the different biogeographical areas.

(i) Tiger Project: To conserve the Indian tigers, so far seventeen places for national parks as well as sanctuaries have been selected for tiger project, such as Sundarban in West Bengal, Manas in Assam, Palamou in Bihar, Corbett national park in U.P., Bandipur in Karnataka, Melghat in Maharashtra etc.

(ii) Rhinoceros Project: In India one horned rhinos are now restricted only in West Bengal and Assam. This wild animal is in danger of extinction. So State Govts, of Bengal and Assam sponsored this project. Through this project, rhinos are now protected mainly in the Jaldapara sanctuary in W. Bengal and Kaziranga sanctuary in Assam.

(iii) Crocodile project: Crocodiles are also declining; so many places have been selected for this project. Aim of the project is to collect their eggs from shores, after hatching, rearing is done in the nursery tanks. Sundarban in West Bengal, Nandankanan in Bhubaneswar (Orissa) etc., have been selected for this project.

14.4.5. RED DATA BOOK:

Wild species that are facing the risk of extinction are enlisted in a book known as Red data book or Red Data Book is the name given to the books dealing with threatened plants and animals of any region. Many countries have prepared their own Red Data Books. On the globel level, in 1963, this red list of species is done by IUCN (International Union for the Conservation of Nature and Natural Resources). Red data book or Red list gives information about the threatened species as well as the urgency of their conservation problems to the public and policy makers. Since 1963 evaluation of the conservation status of species is continuing throughout the world. Red List of IUCN in the year of 2000 is the most comprehensive one, stating the conservation status of plant and animal species of the world. The Red List also provides information about the endangered species of wild flora and fauna.

On the basis of Red data book, there are 54 endangered animals and 113 endangered plants in India. Examples of threatened species in India are: (i) in animals—Pigmy hog (Sus salvanius) and Red Panda (Ailurus fulgens) (ii) in plants—Berheris nilghiriensis and Bentinckia nicobarica.

14.4.6. GREEN DATA BOOK:

Green Data Book is the name given to the book dealing with rare plants which are growing in protected areas.

Green book for India has been brought about. It deals with about a hundred rare plant species growing in garden of Botanical Survey of India.

The Green Data Book is the unique example in the world conservational practice, since it applies a new conceptual approach to conservation of biodiversity. The book provides information about *rare plant* communities in need of conservation and protection. Various types of vegetation are listed in the Green Data Book, such as forest communities meadow, water vegetation, swamp and shrub plant communities.

Table-1 Important protected animals in Sanctuaries and Reserve forests of West Bengal:

Name of Sanctuary/ Reserve Forest	Name of District	Important wild animals
1. Jaldapara	Jalpaiguri	One horned rhino, bison, elephant, tiger, sambar, wild boar, deer etc.
2. Garumara	57	One horned rhino, elephant, tiger, sambar, wild boar, deer, bison etc.
3. Chapramari	,, Darjeeling	Elephant, tiger, sambar, deer etc. Elephant, tiger, deer, pig etc.
4. Mahananda 5. Sinchal	Darjeeting	Himalayan bear, deer etc.
6. Luthian Island 7. Sajinakhali	24-Parganas (s)	Crocodiles, wild pig, otter etc. Tiger, crocodile, wild pig, otter etc

Table-2 Some Extinct animals in India and abroad:

Name of the extinct bird	Name of a country
1. Dodo bird	Mauritus
2. Passenger pigeon	North America
3. Pink-headed duck	Eastern India
4. Mountain quail	Northern India
5. Zordon Coursar	Southern India
6. Pahari boter	North-western India.

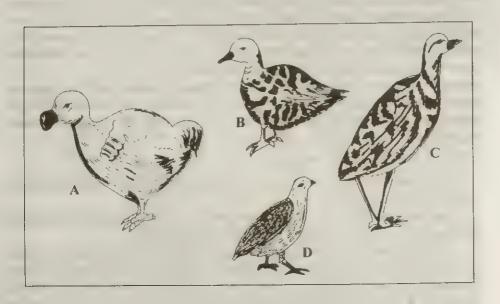


Fig. 14.2: Showing some of the extinct birds (A) Dodo, (B) Pink headed duck, (C) Zordon coursar, (D) Pahari boter.

Table-3 Some Endangered animals in India and abroad:

Name of endangered animals	Name of a country	
Giant panda Orangutang White Rhinoceros	China Sumatra and Borneo Africa India	
4. Asian lion5. Tiger6. Single-horned rhinoceros	,, ,,	
7. Musk deer 8. Snow leopard	19	
9. Wild ass 10. Great bustard bird	27	

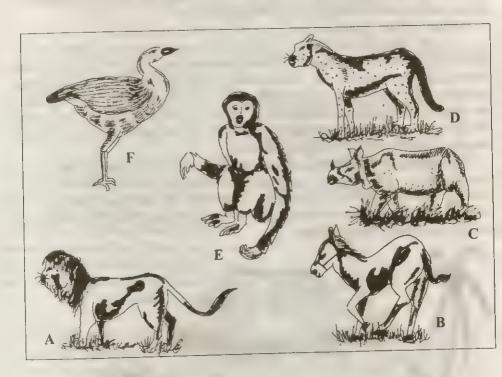


Fig. 14.3: Some endangered animals. (A) Asian lion, (B) Wild ass, (C) Single horned rhinoceros, (D) Leopard, (E) Holook, (F) Bustard

14.5. Insects and their Products

Many insects of the animal kingdom have tremendous beneficial effects to the mankind. To achieve this, man has identified the beneficial insects. They have done much for rearing the beneficial ones. Many industries have been developed depending on the beneficial insects and their products. Man is trying to get more benefit from these beneficial insects through the scientific rearing. As for example, by scientific rearing of the silkmoth, men are trying to produce more silk fibre, by scientific rearing

of the honey bee men are trying to collect more honey and wax, man is rearing the lac insect scientifically to get more lac. Beneficial effects of three insects along with their rearing processes and productions such as silkmoth, honey bee and lac insect are given below in short.

14.5.1 SERICULTURE:

Sericulture is an industry for the production of natural silk. This natural silk is secreted by the larvae which is regarded as silk-worm and the insect is called silkmoth.

- Definition: The scientific process of rearing the larvae of silkmoth for production
 of the cocoon and the extraction of good quality of fibres from these cocoon is known
 as sericulture.
- Sericulture Practices: Important aspects of sericulture is the rearing of larvae. The rearing of larvae needs a healthy and an abundant growth of food-plants. Thus sericulture has three different aspects, such as (i) rearing of larvae. (ii) cultivation of food-plants and (iii) reeling of thread from cocoon.

Mulberry type (Bombyx mori)

- (a) Cultivation of Food plants: The larvae of Bombyx mort feed only on leaves of mulberry plant. So they are regarded as monophagous insect. The larvae get the protein content from the mulberry leaf, as the protein is essential for the silk. So the proper cultivation and production of good quality of mulberry leaf with high protein content are essential for the development of sericulture. So proper care should be taken during the cultivation and propagation of mulberry plant. For rearing of larvae, a continuous supply of healthy mulberry leaves is essential.
- (b) Rearing of Silkworms: The programme of the silkworm rearing depends on the availability of the mulberry leaf as well as facilities for rearing of silkworms, i.e., suitable rearing room and equipments. Equipments for silk-worm rearing are as follows—(i) Rearing trays or Feeding Trays (ii) Rearing stand (iii) Nets for cleaning and (iv) Mountage (Spinning tray).



Fig. 14.4: Diagram showing the Ideal Rearing room of larvae.

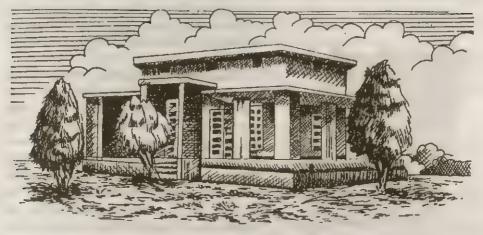


Fig. 14.5: Diagram showing the ideal Rearing room of larvae.

The programme of rearing can be started either from the disease free eggs or from

good seed cocoons. Male and female moths immediately after emergence from the cocoon have a tendency to copulate. After three hours of copulation, the females are separated, each female is then placed on a piece of card board. Each female lays about 300-400 eggs in the next 24 hours. These eggs are very small in size and the eggs remain attached with the card board. They hatch between 7-10 days. These small larvae are known as caterpillars. For proper growth and development of silk-worms, the temperature inside the rearing house should be 70° to 75° F with similar percentage of humidity.

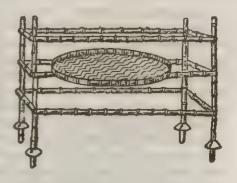


Fig. 14.6: Showing the rearing tray (bamboo) on the shelf of a bamboo-made stand.

(i) Rearing trays: Freshly hatched larvae (5-7 mm length) are transferred to the rearing trays. The tender mulberry leaves cut into small pieces are sprinkled over the egg-sheet of the rearing tray. Now the trays are kept on the rearing stand. These larvae feed voraciously upon mulberry leaves and grow very quickly. After 4-5 days there is first moulting. The larvae of 2nd stage now become slightly larger in size.

The larvae repeat this process of moulting for four times. After each moulting there is increase in the size of larva and all they stages of larvae are fed with mulberry leaf. Now the maturity is achieved in about 22-27 days since the time of hatching and the matured larva measures 7-10 cm. in length. By this time there is development of a pair of silk glands and the matured larvae stop feeding.

Nets: Nets are used for bed cleaning of the rearing tray. The net is uniformly spread over the rearing tray and chopped mulberry leaves are placed over the net. The

larvae crawl through the net and after entering they feed on the fresh leaves. Now the

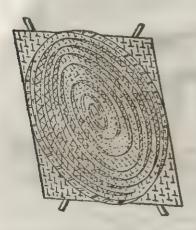


Fig. 14.7: Diagrammatic representation of a bamboo-made spinning ray (mountage).

net along with the larvae are transferred to a new rearing tray. Later the old tray with excreta of larvae, unused mulberry leaves etc., is cleaned.

Mountage (Spinning tray): When the fully matured larvae stop feeding, they are transferred to mountage or spinning tray. Now they begin to secrete the sticky secretion from the silk gland through a very narrow pore of spinneret on the hypopharynx of the larvae. This sticky thread becomes wrapped around the body of larva and this spinning continues for 2-3 days. At the end of spinning, the larva is enclosed within a thick, hard, oval whitish or yellowish cocoon. The larva is then transformed into a brownish pupa, each cocoon is made up of continuous thread.

Harvesting of Cocoons: The time of harvesting as just after the formation of cocoons. Cocoons are normally harvested by hand. Healthy cocoons are selected and kept in cages for the next crop and these cocoons are regarded as seed cocoons. Rest amount of cocoons are utilised for the production of raw silk.

(c) Reeling of Raw Silk from Cocoon: The reeling and raw silk production is the second stage of the silk industry. Before emergence of the moth, the cocoons are boiled in a basin. After boiling, the gum of the cocoons gets softened and the filaments are loosened. As the single filament of a cocoon is so thin that the filaments of several cocoons (5/10/15) are passed through the 'glass eye' on to the reel. The thread thus reeled forms the 'raw silk' of commerce. This kind of fibre is called as reeled silk. In India, about 1 kg. of raw silk is obtained from nearly 16 kg. of green cocoons.

[d] Production of Silk: Silk is the secretory substance of two silk glands which are located on the ventro-lateral sides of the alimentary canal of the larva. Both the glands are connected with a very narrow tube like structure known as spinneret, which is situated on the floor of the mouth of larva. The liquid secretions of two glands passes through the spinneret due to contraction and expansion of the body of larva. This sticky secretion of the silk glands is passing through the spinneret and after coming in contact with the air is converted into a fine, long and solid thread of silk.

[e] Properties and Chemical Composition of Silk: Silk threads are very fine, soft and light in weight. Though the threads are very thin yet they are strong having

high elastic property.

The silk thread is composed of two types of **protein**, namely **fibroin** and **sericin**. The main inner core is made up of fibroin (true fibre) and the fibroin is surrounded by a thin covering known as sericin. Fibroin is 75-80% of the fibre and the rest 20-25% is the sericin. There is also little quantity of waxy and colouring material. Fibroin is insoluble in water and is made up of glycine, alanine and tyrosine. Sericin is easily soluble in water.

[f] Utility of Silk: Pure silk is one of the finest and most beautiful natural fibres of the world. So it is said to be the 'queen of fibres'.

- 1. Bulk of the silk is utilised in preparing silk clothes in India as 'saree'. Silk is also utilised in the preparation of Dhoti, Bush shirts, handkerchiefs, scarves, stoles, ties, shawls etc. Many textile industries are manufacturing clothes in which silk fibres are combined with other natural and synthetic fibres, namely terysilk, cotsilk etc.
- 2. Besides silk being used as garments it is also used in other industries and for military purposes. Silk is used in the manufacutre of parachutes, insulation coils for telephones and wireless receivers, tyres of racing cars, filter clothes for flour mills, type-writer ribbons and in medical dressings.

14.5.2 APICULTURE:

• **Definition**: Apiculture is the technique of scientific rearing of honey bees and extracting honey and wax from their hives.

Different Species of Honey Bee

The Honey bees belong to the order Hymenoptera, and come under the class Insecta of the Phylum Arthropoda.

There are three recognised types of bees found in our country, such as (i) Apis dorsata (Rock bee), (ii) Apis florea (Little bee), (iii) Apis indica (Indian bee).

The European honey bee, Apis mellifica has been introduced to many honey producing countries of the world. This bee is similar to Apis indica and both are domesticated for Apiculture.

Characteristic features of three Indian bees are given below:

1. Apis dorsata which is commonly known as Rock bee, is the largest Indian variety. The average size of bee is about 20 mm. It builds large comb or hive on branches of tall trees, rocks and ceilings of deserted buildings. This type of bee has the highest honey yield (average 15 kg. per hive per year) amongst Indian bees. This type of bee is wild variety.

2. Apis florea is commonly known as 'little bee'. It is seen only in the plain areas. It builds small hive on the branches of trees, or in bushes or in buildings. This type of

hive yields about 0.5 kg. honey.

3. Apis indica is commonly known as Indian bee. It is found all over the country on the plains and forests of India. It builds hive in protected places like crevices of trees, hollows of rocks and other covered places. Each hive yields 4–4.5 kg. of honey. It is the best of the Indian variety because of their gentle temperament. Bees are easy to handle and they form hive even in artificial wooden boxes.



Fig. 14.8: Three different castes in a colony of honey bees.

LIFE CYCLE OF HONEY BEE:

During breeding season, the queen bee together with the drones fly out of the hive. This is called **nuptial flight** or marriage flight. In this nuptial flight, only one drone copulates with the queen in the air. The drone then looses its copulatory organs and ultimately dies. The queen stores the sperms in the spermathecae. After returning to the hive, queen starts laying eggs. The queen can lay both fertilized and unfertilized eggs. It is believed that the process of egg laying is under the voluntary control of the queen.

The queen lays one egg in one brood cell. Eggs are small, whitish and spindle shaped; they are attached to the bottom of the brood cell. Larvae are hatched both

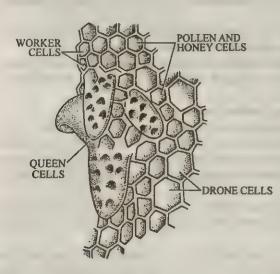
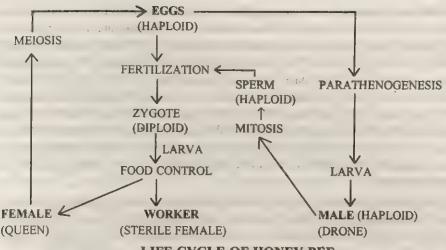


Fig. 14.9: A portion of comb of honey bee.

from the fertilized as well as unfertilized eggs after about three of laying. days egg Parthenogenetically male larva is developed from unfertilized egg but the female larva is developed from fertilized egg. During first 2-3 days all larvae are fed with the 'Reyal jelly' which is secreted by the pharyngeal glands of the young workers. The royal jelly is a special food which consists of digested honey and pollen, mixed with a glandular secretion from the mouth of the workers. After that period, 'Bee bread' is given to the larvae. The bee bread is a

coarser food which is a mixture of honey and pollen grains. However the queen forming female larva is fed on 'Royal jelly' for full larval period. The larvae moults several times. After 6 days of feeding, the worker bees cover the brood cell with a thin layer of wax. Inside the brood cell, each larva spins a delicate silken cocoon. Now the larva turns into a pupa. During the pupal stage, legless white larva undergoes metamorphosis. Finally the adult comes out after two weeks. Thus the larvae which develops from unfertilized egg are fed with first royal jelly and then with bee bread, ultimately give rise to drones. The larva which develops from fertilized egg fed with royal jelly throughout the larva period, ultimately gives rise to queen; but the larvae from fertilized eggs if fed with royal jelly first and then bee bread will form workers. The workers are actually females but they are sterile. It is thought that the differential type of food given to larvae lead the degeneration of body size and reproductive organs. Worker bees just after emergence to adult start working and their duties change with the advancing age.



LIFE CYCLE OF HONEY BEE

BEE-KEEPING IN WOODEN BOX :

Scientific method of bee keeping has been developed after studies of behaviour of bees, their way of functioning and mode of reproduction. The discovery of the principle of movable frame hive by **Rev. Langstroth** in 1851 gave an impetus to bee-keeping.

An artificial movable hive is constructed by wooden box, which is based on bee space theory. This is a space to permit the entrance and exit of workers and drones but queen once place in hive never comes outside the hive. Typical movable hive consists of the following parts:

- (a) Stand—It is a four legged stand on which the whole hive is constructed. A slanting piece of wood which is known as 'alighting board' remains fixed with the stand.
- (b) Bottom board—It is made up of wood and is situated above the stand. It is the proper base for the hive provided with an entrance aperture for the worker bees.

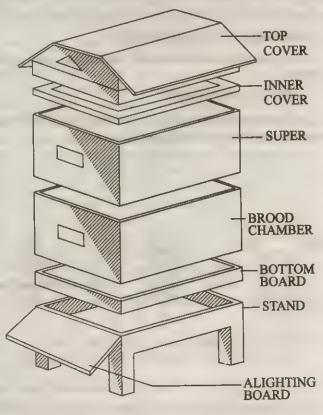


Fig. 14.10: Outer view of a Langstroth Wooden frame hive.

- (c) Brood Chamber. It is a rectangular wooden box without top and bottom. It is placed on bottom board. Inside the brood chamber, 5. 10 frames are hanging vertically from the top. These frames can be removed independently, hence the modern hive is called as movable trame hive. The distance between the two frames of brood chamber is known as bee space. This space serves as a passage for the movement of the bees. In each frame, a way sheet is fitted. This way sheet is marked with hexagonal shape on both sides of the sheet, bach sheet of way with hexagonal markings is known as comb foundation. This comb foundation provides the base for the comb preparation on both the sides. The brood chamber is covered over by a frame of metallic wire known as queen excluder. Through this queen excluder, the workers can easily pass but the queen cannot pass.
 - (d) Super The brood chamber is covered by another similar chamber known as Super It is also without any cover at the top and the base. Super is also provided with many frames with comb foundation. This chamber is meant for the storage of honey. In this chamber queen cannot enter due to the presence of queen excluder.
 - (e) Inner Cover Super is covered externally by a wooden piece which is known as inner cover. This inner cover is provided with many holes, for proper ventilation of the hive.
 - (t) Top Cover This cover is placed on the top of inner cover. The top cover is fitted with zinc sheet which is plain and sloping. This is treated as the roof of the wooden box. Hence the top cover is meant for protecting the hive from rains.

• PRODUCTS OF HONEY BEE:

There are two main products of bee keeping industry, such as (1) Honey and (2) bee wax.

14.5.3. LAC CULTURE

Lac insect belongs to the Phylum Arthropoda, Class: Insecta and Order: Hemiptera. Scientifically this insect is known as Tachardia lacca.

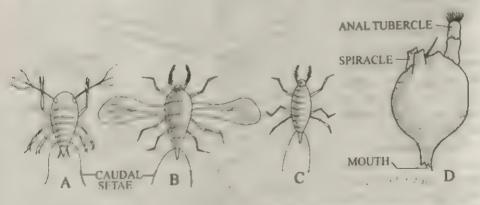


Fig. 14.11: Lac insect. [3] Nemph [B, Male (winged) [C] Male (Wingless) [D] Female (Adult)

Lac is regarded as resmous substance which is secreted by the members of lac insect. In order to obtain more lac, these insects are cultured and the technique of lac

production is called **Lac culture**. It involves proper care of host plants, regular prunning of host plants, propagation of insects, collection and processing of lac. Before coming to the cultivation of lac insect, we must acquire the detailed knowledge of lac insect and its life history. The adult lac insect shows a phenomenon of sexual dimorphism. The male and female lac insect vary in shape, size and certain body parts.

MALE LAC-INSECT: It is a tiny insect and length of which is 1.2.1.5 mm. Insect is red in colour. The head bears a pair of antennae and a pair of eyes. Mouth parts are absent. Hence a male adult is unable to feed. Thorax bears three pairs of legs. One pair of wings may or may not be found. Abdomen is long with eight segments. A pair of caudal setae is present at the posteror end of the abdomen.

FEMALE LAC-INSECT: The length of female lac is about 4-5 mm. The pyriform body of the female is enclosed in a resmous cell. The head, thorax and abdomen are not clearly distinct. The month parts are of piercing and sucking type. Eyes are absent. Wings and legs are absent.

LIFE HISTORY

After attaining maturity, males emerge from their cells and walk over the lac merustations. The mature male enters the female cell through anal tubercle and fertilize the female. After copulation, the male dies. Fertilized female then lays eggs (200–500) in the cell in which female is enclosed. The eggs are developed inside the **incubating chamber** which is formed by the contraction of the body of the female. Inside the incubating chamber of the female, the eggs hatch into larvae after about 6 weeks

Larva: When large number of larvae emerge from the incubating chambers, it is known as swarming. These larvae are minute and they are about 0.5 mm in length They are red coloured and boat shaped. These larvae start moving in search of food and reach the tender shoots of the host plant. When they get fixed with the twig, they start sucking the sap of the host plant by means of piercing and sucking mouth parts. In the mean time, the larvae begin to secrete resinous substance around their body. Subsequently each larva gets fully covered by the resinous substance to form a lac cell. As the larvae settle very close to each other on the twig, the coatings of cells fuse completely. Thus a continuous covering of lac is formed on the twig. The male cell is elongated and eigar-shaped having anterior and posterior holes and the female cell is oval having a pair of small pores on the side and a single round pore on the posterior end of the cell. Larvae moult in their own cell and begin to feed actively, after 6-8 weeks, the larvae are metamorphosed into adult insects. The male and female insects emerge through the posterior end of the cell. The females get fixed on the host plant in the resmous mass, the males come out of the cell and walk over lac encrustations and enter the female cell for fertilization. After fertilizing the female, males come out of the cell and enter to another female cell, thus one male can fertilize many females. But in case of female, after fertilization there is rapid growth till it begins to lay eggs. The life span of female is longer than male. In this process the life cycle is completed

HOST PLANTS:

Lac insects live as a parasite on host plants. They are sucking the sap of certain trees. The important trees on which the insects thrive and breed are given below

Kusum: Schleichera trijuga Palas: Butea frondosa Ber (kul): Zizyphus jujuba Babul: Acacia arabica Khair: Acacia catechu Sal: Shorea robusta

CULTIVATION OF LAC:

Cultivation of lac involves proper care of host plants, inoculation, swarming period

and harvesting of lac. The most important of lac cultivation is the proper care of host plants. The host plant should be pruned in January or June every year. In the host plants, lac insects

depend for their food, shelter and completion of their life cycle.

Inoculation: The method by which the larvae of lac insects are introduced to the new host plant is known as inoculation. Inoculation occurs by two ways-natural and artificial.

(i) Natural inoculation: The inoculation that takes place by natural movement of

the larvae on the host plant is called natural inoculation.

(ii) Artificial inoculation: Inoculation that takes place through the agencies other than those of nature is known as artificial inoculation. In this method, just before hatching, lac bearing twigs are cut to the size of six inches length. Then the cut pieces of these twigs are tied to fresh tender branches of the tree. After swarming of the larvae, these twigs are removed from the host plants.

Harvesting of lac crop: The process of collection of lac from host plant is known

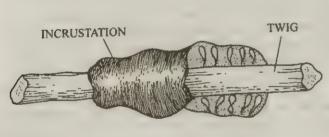


Fig. 14.12: Incrustation of lac around a twig.

as harvesting. The lac insects complete its life cycle twice in a year. The lac that develops in kusum plant is called as 'Kusmi lac' and that develops on non-kusum plants are called as 'Ranjeeni lac'. The kusmi lac is said to be the best lac.

Processing of Lac: The twig bearing the lac

along with eggs is known as brood lac stick and the lac is known as Stick lac. The scraping of the stick lac from the twig is done by knife. The scraped lac is grinded in stone mills. The impurities are removed from the scraped lac as well as from grinded material. Subsequently the grinded lac is washed repeatedly with cold water and dried in sun light. These dried granules are known as seed lac. Seed lac is then melted in a cloth bag, which is twisted and the lac is squeezed out of the bag. The final form of lac in known as Shellac.

COMPOSITION OF LAC:

Lac is a complex substance which is mainly composed of resins along with various ingredients. The percentage of which are given below:

ercentage of which are given	DCIOW .
Resin	68-90%
Albuminous matter	5-10%
Dye	2-10%
Mineral matter	3-7%
Wax	6%
Water	3%
11 2000	

ECONOMIC IMPORTANCE OF LAC:

Lac has been used for the welfare of human beings. Hence there is great commercial value of lac. These are given below:

1. Lac is used in the manufacture of toys, ornaments, gramaphone records, sealing

wax.

- 2. Lac is also used in the manufacture of varnishes and paints.
- 3. It is used for silvering the back of mirror, insulating cable wires.
- 4. Byproduct of stick lac is used for dying purpose as in nail polish.

14.6. Biotechnology and its Benefit

Biotechnology is the subject of the decade, it simply means applications of biology towards human benefit.

Definition: Biotechnology is the integrated application of knowledge and techniques of biochemistry, microbiology, genetics to derive benefit in the technological level involving micro-organism. The oldest biotechnological process is recorded is a Babylonian tablet, dated 6000 BC, unearthed in 1981, which depicts the preparation of beer by the process of fermentation.

The following events have paved the way of modern biotechnology:

(i) Avery, McLeod and Mc Carty (1940) denoted bacterial transformation.

(ii) Watson and Crick (1953) denoted the DNA double helix.

(in) Nirenberg and Khorana (1963) denoted genetic code.

(iv) Merrifield (1963) first manufactured the synthetic polypeptide.

(v) Arber, Smith and Nathans (1972) developed the restriction enzymes or genetic knife for cutting DNA.

(vi) Itakura (1977) assembled the genes for human insulin and somatostatin and in

1980, he produced the first gene assembler.

14.6.1. AREAS OF BIOTECHNOLOGY:

The major areas of biotechnology and the principal products are as follows:

Ine	The major areas of biotechnology and the principal party		
	Areas	Products	
[1] [2]	Recombinant DNA technology Cell cultures	Enzymes, vaccines, interferon, hormones. Biomass, single cell proteins, fine chemicals, blood products and monoclonal antibodies.	
[3]	Waste treatment	By product utilization, recovery of cellulose, water recycling.	
[4]	Enzymes and biocatalysts	Food processing, fine chemicals, diagnostic kits, chemotherapeutic agents, biosensors, ethanol.	
[5] [6] [7]	Fuels Nitrogen fixation Pharmaceuticals and fermentation products	Alcohol, hydrogen, methane. Nitrogen fertilizers. Antibiotics, vitamins, aminoacids, nucleotides, steroids, citric acids, bio-polymers, acetone, ethanol, butanol and bio gas.	

14.6.2. BROAD OUTLINE OF GENE CLONING PROCEDURE:

Gene cloning is the most important event of Genetic Engineering procedure.

Definition of Gene Cloning: It is essentially the insertion of a specific foreign DNA into a cell in such a way that the inserted DNA is replicated and produces a large number of identical daughter cells.

The major steps of gene cloning are as follows:

[1] Breaking of cells: The cells are broken in a blender and then treated with

[2] Isolation of DNA from the cells: The DNA molecules are taken out of the detergent. fragmented cells by spooling it out with a glass rod and then it is taken out of the living cells.

[3] Cutting off of desired genes: The desired genes are cut off with the help of specialized enzymes called restriction endonucleases or genetic scissors.

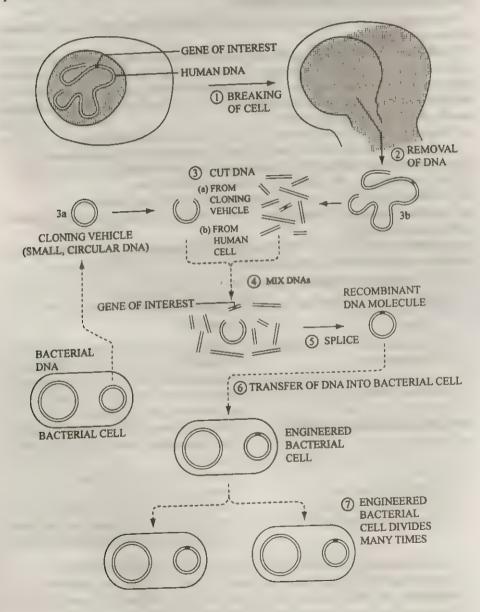


Fig. 14.13: Major steps of gene cloning.

- [4] Incorporation of the desired gene into a vector: The desired genes are incorporated into a specific cloning vehicle or a vector, which is usually a plasmid or phage DNA. These cloning vehicles are usually short sized DNA molecules, which can easily penetrate living cells and multiply within it. After incorporation, the chimeric DNA molecule of the recombinant DNA is made to enter a host cell. The host cell is usually a bacterial cell or yeast cell.
- [5] Multiplication of the recombinant DNA molecule: This is done by repeated multiplication of the host cell, along with it the recombinant DNA also multiply and millions of clone containing the desired gene is produced.

Cloning is not the ultimate step, because the information in the DNA must be converted to an useful product. For this purpose, the information in the DNA is to be transferred to a proper site, where it can express itself and the economically important product in the form of a protein is produced *e.g.* Production of human recombinant insulin.

Benefit of Biotechnology:

The major benefits of biotechnology lies in the production of transgenic microbes, plants and animals, which are useful for various economic purpose. But it is worth mentioning here that the issue of producing transgenic organisms or genetically modified food is highly controversial and may involve mixed reaction in different countries, so the issue should be dealt with due caution.

(a) Transgenic Microbes:

- (i) Production of Single Cell Proteins: The protein rich micro-organisms is used as single cell proteins, their protein content is improved through improved culture technique or exploitation of gene. These organisms include algae like Chlorella, Spirulina, fungi like Saccharomyces cerevisiae, Candida utilis, Penicillium cyclopium, Trichoderma harzianum; bacteria like Methylophilus methylotrophus.
- (ii) **Production of vaccines:** The *Vaccinia* virus Ankara is utilized to produce experimental vaccine against Human Immunodeficiency virus. The portion of the genome of *Vibrio cholerae* responsible for the production of cholera enteratoxin was deleted by recombinant DNA technology and the attenuated bacteria is utilized to produce vaccine against cholera. The purified vili of bacteria *Neisseria gonorrhoeae* is utilized to prepare vaccine against gonorrhoea. The antigen encoding gene for providing resistance to Anthrax was identified and vaccine was prepared.
- (iii) Production of primary and secondary metabolites: The primary metabolites like amino acids, vitamins, pigments are improved in common microbes like Ashbya gossypii, Aspergillus niger. The secondary metabolities like antibiotics are developed in species of actinomycetes like Streptomyces, Cephalosporium and bacteria like Bacillus spp.
- (iv) **Production of Fuel:** The bacteria like *Thermoanaerobacter ethanolicus* is developed by genetic engineering and it became more efficient than yeast in the production of ethanol, used in fuel mixture.
- (v) Bio-mining: The bacteria Thiobacillus feroxidans is developed, so that it not only solubilizes iron, but also cobalt, nickel and lead.

- (vi) Nitrogen fixation: The nitrogen fixing (Nif) gene from Klebsiella pneumoniae when transferred to E coli via pRDI plasmid successfully activated the nitrogenase (enzyme fixing nitrogen) activity. The Azotobacter vinelandu mutant, which lacked the ability to fix atmosphetic nitrogen successfully resume nitrogenase activity in presence of pRDI plasmid contaming the Nif gene. This happened even in presence of oxygen, though the gas has an inhibitory action on nitrogenase.
- (vii) **Biofertilizers**: These include bacteria and blue green algae having the ability of nitrogen fixation. Genetic manipulation of common nitrogen fixing blue green algae like *Nostoc* increases their reproductive rate and there by increases the fertility of the soil.
- (viii) **Bio-degradation**: The process of bio-degradation involves conversion of complex organic pollutants to simple soluble substances. This can be efficiently carried out by micro-organisms. Species of *Nocardia, Streptomyces* can efficiently degrade complex hydrocarbon. Professor Ananda Mohan Chakraborty patented *Pseudomonas putida* for efficiently degrading petroleum derivatives and reducing the hazards of oil spill. The reconstructed *Pseudomonas putida* also exhibited the ability to degrade xylene derivative.
- (ix) **Hydrocarbon Production**: The unicellular algae *Botrycoccus brauni* can be used for the production of hydrocarbons, which are used in the petroleum production. The hydrocarbon is primarily deposited in the cell wall. The colour of the algae depends on the hydrocarbon deposited.
- (x) **Production of Hydrogen fuel:** Bacteria have the ability to produce hydrogenase enzyme, which can be utilized in the production of hydrogen fuel. These genes can be transferred to other cyanobacteria and there by the generation of hydrogen fuel can be increased.
- (xt) Control of Malaria: The Bs toxin producing gene from Bacillus sphaericus is transferred to aquatic blue green algae, which destroys mosquite larvae in the water body.

(b) Transgente plants:

- (i) Resistance against virus: The DNA for the protein coat of TMV has been identified and when transferred to tobacco plant conferred resistance to tobacco plant against TMV. Similar 35S promoter gene from cauliflower mosaic virus also produced transgenic resistant plants. In the same way, the protein coat gene transcript has also been used to provide resistance against potato leaf roll virus.
- (ii) Resistance against bacteria: The genes for the synthesis of different antibacterial compounds like lysozyme, cercopins have been identified in the giant silk moth *Hylophora cecropia*. The transfer of these genes to crop plants impart resistance to different pathogenic bacteria.
- (iii) Resistance to Fungi: (1) The protein called attacin producing gene isolated from the silk moth *Hylophora cecropia*, transferred to potato plants made it resistant against *Phytopihora infestans* causing late blight disease.
- (2) The Ribosome Inactivating Protein (RIP) gene isolated from barley plant when transferred to tobacco plant made them resistant against the Rhizoctonia soloni.

(3) The phytoalexin producing genes from resistant plants when transferred to susceptible crop plants like rice, pea, beans, soybean made them resistant against the following fungi.

Name of the crop	Phytoalexin	Name of the pathogen to which it is resistant
(i) Oryza sativa (Rice) (ii) Pisum sativum(Pea) (iii) Glycine max (Soybean) (iv) Phaseolus vulgaris (Bean)	Momilactone Pisatin Glyceolin Phaseolin	Rhizoctonia solani f. sp. sasakii. Peronospora pisi. Myrothecium roridum. Macrophomina phaseoli.

- (4) The transfer of Oxalate decarboxylase (OXDC) gene to chickpea makes it resistant to Fusarium wilt disease.
 - (5) The same gene (OXDC) makes tomato plant resistant to Sclerotinia infection.
- (6) The upgradation of Pathagenesis-Related (PR) protein like Zeamatin in maize and Osmotin in tobacco increases their antifungal properties.

(iv) Resistance to Insect:

- (1) The *Bacillus thuringiensis* is a bacteria that produces Bt toxin, which destroys a large variety of insect pests. This gene when transferred to cotton and tomato plants, make them resistant to various lepidoptera and diptera insects, because these plants can produce the Bt toxin. Though they also exhibit antibiotic resistance because of this transgenesis.
- (2) Insecticidal gene from Baculo virus when transferred to tomato and tobacco plants makes them resistant to various lepidoptera, coleoptera and diptera insects.
- (3) HSI gene from *Hyoscyamus*, when transferred to sugar beet, make them resistant to nematodes.
- (v) Stress resistance: (1) The MTLT gene (capable of inducing manitol production) increases higher osmotic concentration within the cell, which makes the rice and tobacco plant resistant against salinity and draught stress.
- (2) Salinity stress in rice plants can be brought about by the inactivation of porter genes, responsible for the intake of Na* ions. It is done by the activation of a set of genes called antiporter genes.
- (3) In tobacco plants, the mechanism of salt tolerance is brought about by the activation of an enzyme system called glyoxalase I and glyoxalase II, along with that, there is an activation of G. proteins (glutathion).
- (vi) Increase of vegetable shelf life: The α , D-monoxidase gene is isolated from Lathyrus (sweet pea) and its infusion in the tomato plant followed by its expression increases the shelf life in tomato.
- (vii) **Delay of Senescence**: The delay of senescence can be brought about by the treatment of cytokinin. But the gene responsible for the synthesis of Iso-pentenyl transferase (IPT gene), when transferred to tobacco plant, delays its senescence.

(viii) Nutritional Upgradation in Crop plants:

- (1) The β carotene producing gene from daffodil, when transferred to rice plant, produces golden rice, which can produce vitamin A and there by prevent night blindness in young population.
- (2) The deficiency of iron in rice plant can be met by introduction and expression of ferritin gene from soybean.

(3) The AmA I gene from Amaranthus plant when transferred to potato, localizes itself within the cytosol of potato and its productivity was increased along with the increase in protein content. Similar results was obtained in case of rice, cassava and

sweet potato.

(4) The legume plant Lathyrus sativas is rich in protein, but it contains a neurotoxin called **oxyl diamino-propionic acid**, which makes it unsuitable for human consumption. The enzyme oxalate decarboxylase (OXDC) breaks the oxalic acid and there by prevents the synthesis of the toxin. This gene for preparing OXDC was isolated from an edible fungi and when transferred to Lathyrus, makes it nutritionally important without any side effect.

(5) The genetically modified rice containing the Agrobacterium gene shows a

remarkable increase in starch content by 20-30%.

- (6) The maize plant can carry out C₄ pathway because they contain the enzyme PEP carboxylase. The genes responsible for the synthesis of PEP carboxylase was indentified (PEPC) and it was observed to be a cluster of 4 genes. These genes were identified step by step into rice plants and there by a more productive rice in terms of PEPC rice was obtained.
- (ix) **Production of bio-plastic:** The genes responsible for the production of polyhydroxy alkanoate polymer (biologically degradable plastic) was identified in a bacteria *Chromobacterium violaceum* and its transfer to higher plants can produce plastic yielding plants.

(x) **Bio-fuel**: The hydrocarbon content of artichokes can be improved by genetic engineering and these G. M artichokes can be used as a bio-fuel.

(c) Transgenic animals:

(i) Hybridoma and Monoclonal Antibody: Hybridoma is a technique involving formation of hybrid cell line by the fusion of a normal lymphocyte with a myeloma cell. The monoclonal antibody is a single type of antibody molecule obtained with the help of hybridoma technology. Its advantage is that, it is derived from a single cell and comprises of a uniform breed of antibody specific for a single antigen site.

(1) It helps in the identification of cells taking part in immune response like the

helper T cell, supressor T cell etc.

(2) It prevents tissue rejection in cases of kidney or other organ transplant by suppressing the immune response.

(3) It helps in the diagnosis of various diseases including cancer.

- (4) It helps in the purification of protein. There is a particular hazard involved with the use of monoclonal antibody, which is that it may contain virus that might increase the incidence of cancer.
- (ii) Production of transgenic animals: The production of transgenic animals is not a common method. Transgenic mice have been produced through viral vectors, micro injection and electroporation which has the greater ability to produce the growth hormone. These discoveries can be used in the treatment of human diseases or production of improved varieties of cattle products.
- (iii) Production of Interferon: They are a group of small proteins with molecular weights 20-30 kd. It can be broadly classified as IFN α , IFN β and IFN γ . Apparently interferons do not kill virus, but it prevents its replication within the cell. When it was

initiated in cultured cells, the production was low, it was tackled by using genetic engineering involving the alcohol dehydrogenase enzyme gene of yeast.

- (iv) Detection and cure of congenital abnormalities: Haemoglobin biosynthesis is incomplete in certain diseases like β -thalassemia and sickle cell anaemia. In case of β thalassemia, the β globin is not synthesized because of the mutation in the 17th and 39th codon. Sickle cell anaemia is due to the change of the 6th amino acid in the β chain of haemoglobin, when glutamic acid is replaced by valine. Once the cause is identified, the mutated genes can be removed by restriction endonuclease and replaced by normal DNA fragment. This is termed as **gene replacement therapy**. This phenomenon utilizes the retro-virus vector and cannot be used in some selective genetic disorders. Till date it has been attempted in sickle cell anaemia and phenylketonuria, but much success has not been met with.
- (v) **Development of Stem Cell:** The stem cells are particular cell lines isolated from 6 week old human embryo, which can regenerate into particular organs. Globally 64 stem cell lines have been isolated and in future it can be of tremendous importance in regenerating various organs and curing diseases like Parkinson's syndrome, diabetes etc. But since August 2001, stem cell research has been banned in the United States because it involves destruction of human embryo.

14.6.3. Sperm and Ova Bank: Test-Tube Baby: Surrogate mother:

[1] Sperm and Ova bank:

The technique of storage of sperms and ova at a very low temperature (—195°C) brought about by liquid nitrogen is popular since 1970's. The place where sperms and ova are stored is known as sperm and ova bank.

The main objectives for sperm and ova bank are:

- (i) The human males are gradually becoming oligospermic and so sperms can be stored for future use in artificial insemination and *in vitro* fertilisation (IVF, *i.e.* ferhization outside the body of a woman)
 - (ii) The patients suffering from cancer may have their sperms stored.
 - (iii) The persons going to warfield store their sperms, in case thay do not return.
 - (iv) The sperms of extra-ordinary intellect may also be stored.
- (v) The lady suffering from ovarian cancer may store their ova before the surgical removal of the ovary.
 - (vi) The stored sperms and ova of donors are also used for the childless couples.
 - (vii) They provide sperm and ova for infertility research.

In addition to storage of sperms and ova, they may provide additional services like:

- (i) Cryopreservation of embryos after in-vitro fertilization.
- (ii) Infertility detection.
- (iii) Parenthood confirmation by DNA fingerprinting.
- (iv) Selling of sperms of anonymous donors to licensed physicians for *in-vitro* fertilization programs.
 - (v) Storage of umbelical cord blood and detection of congenital abnormality.
 - (vi) Genetic counseling before marriage to minimize congenital abnormalities.

- (vii) Storage of canine semen for breeding of dog and future cloning.
- (viii) Creation and maintenance of sperm donor on-line list.
- (ix) Analysis of semen.

[2] Test tube baby:

A baby formed by in vitro fertilization is called test tube baby.

The fusion of ovum and sperm is carried out artificially in a laboratory setting, outside the body of a woman (*in vitro*) which produces a zygote and develop into embryo. The embryo is transferred into the uterus of the mother donating the ovum, which develops into a foetus and finally is born as a child. Such a baby is referred to as **test tube baby**.

The first test tube baby was Louise Joy Brown, whose date of birth was 25th July, 1978 in Oldham, Lancashire, U. K. Her parents were Lesley and Gilbert Brown. The baby girl was full term and weighed 5 lbs and 12 oz. The doctors involved in the process were Dr. Patrick Steptoe and Dr Robert Edwards of England, though even before that, Dr. Subhash Mukherjee in Calcutta was successful in artificial insemination, but it was not recognized and the doctor later comitted suicide.

Procedure: The mother is given estrogen injection for the purpose of ovulation. The ovary is located with the help of a laparoscope, the matured ova are removed aseptically from the follicle with the help of a fine glass tube. The ovum is placed in aseptic nutrient broth culture in petridish for a few hours. The semen containing adequate motile sperms are then added to the ovum. Fertilization takes place and then when the embryo is at 4-8 cell stage, it is placed in the uterus of the mother's body donating the ovum, where it developed into a normal child. This technique of test tube baby production is called in vitro tertilization embryo transfer (IVF-ET).

Nowadays with the help of micro injection technique, the sperm may be released inside the ovum cytoplasm with the help of a microscope. This increases the probability of fertilization.

Presently test tube babies are born in majority of the countries including India. The officially recorded first test tube baby in India is a girl 'Harsha' born on 6th August, 1986 at the K. E. M. hospital in Mumbai.

[3] Surrogate mother: A surrogate mother is a woman who by contract agrees to bear a child for someone else. Surrogacy or womb leasing is intended to help a couple, of whom the wife is infertile (due to lack of uterus as in case of hysterectomy or if her uterus is not suitable for conception), but the husband has no reproductive deficiency. It is also used when a lady has problems like anaemia, arthritis etc. so that child bearing is impossible for her. If the wife can produce eggs, the procedure of IVF-ET is adopted using the eggs of the wife and sperms of the husband. The embryos are transferred to the hired woman (surrogate mother), who bears the child in her womb till delivery. Alternately, when the wife cannot produce eggs, the eggs of the surrogate mother can be used. In such cases, the surrogate mother is artificially inseminated with the sperms of the infertile woman's husband. After surrogate birth, the baby is returned to its biological father and his wife.

The principle of surrogate motherhood is allowed in India and other third world countries. It is also allowed in the European Union, but the United States of America is

against this principle of utilization of the uterus of Mrs Y to incubate the fertilized egg of Mrs X. The U.S.A. government have proposed some guidelines against this principle, which include.

- (i) An embryo should not be kept outside the mother's body for a period more than 14 days.
- (ii) The egg and sperm donors involved in artificial insemination and embryo transfer should be married.
- (iii) The Government funded research project would not involve transfer of embryo from one woman to another.

14.6.4. DNA Fingerprinting in relation to Forensic Biology:

The technique of DNA fingerprinting was developed for the first time in 1986 by A. Jeffrey et al in Leicester University in U. K. In this technique, the DNA samples were isolated from blood stain, semen or hair roots, this DNA is subjected to Southern Blotting. In this technique, the DNA fragments are subjected to gel-electrophoresis, then from the agarose gel, it is transferred to nitrocellulose paper and then DNA hybridization is carried out with specific DNA probe, which reveals the similarity.

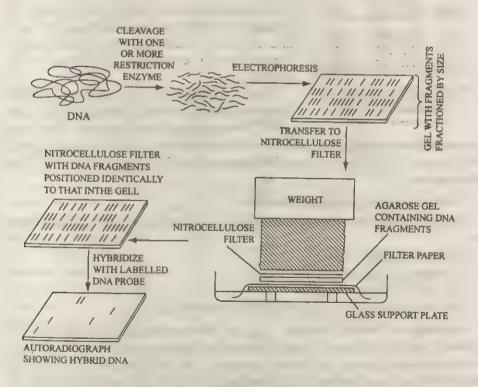


Fig. 14.14: Method of Southern Blotting.

If the DNA fragments are not adequate, it is amplified by **Polymerase Chain Reaction** (K. Mullis, 1985) by which repeated copies of the same DNA fragment is produced. The DNA pattern is unique for an individual as his fingerprint, so two persons descending from the same germline will have almost similar fingerprint.

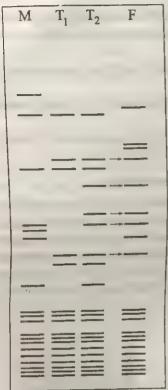


Fig. 14.15: DNA fingerprints of identical twins T₁ and T₂ M: Mother; F: Father.

It is used in the following cases:

- (i) Solving the issue of paternity problems.
- (ii) In forensic biology it has got tremendous importance because it can reveal a person's identity through blood stain, semen or even from a single hair follicle. Thus a murderer can be detected.
- (iii) It can be used to detect a person killed in plane crash by analyzing DNA recovered from the ash.
- (iv) It can even detect the identify of a human bomb (as it was done to detect "Dhanu", in the Rajiv Gandhi assassination case).

In India, it was initiated in the Centre for Cellular and Molecular Biology (CCMB). Hyderabad from 1990 under Dr. Lalji Singh.

14.6.5. GENE MAPPING:

The chromosome mapping or gene mapping is the most challanging task in the present century. It helps us to know the function of each and every gene in a chromosome and there by several genetic irregularities can be rectified by eliminating certain genes.

The first organism, whose gene was mapped completely was the bacteria *Haemophilus influenzae* where 1746 genes have been designated. The human

genome project was undertaken in 1989 and when the draft proposal was submitted in 2001, around 35000 genes were designated in the 22 autosomes and X/Y sex chromosomes.

Techniques involved in gene mapping:

There are four basic techniques employed in the process of gene mapping which are:

- (i) Family linkage studies
- (ii) Segregation in cell hybrids
- (iii) Use of molecular markers
- (iv) Use of Restriction Fragment Length Polymorphism.
- (i) Study of Family Linkage: It is the oldest technique employed in higher organisms including human. It is simply the study of linkage groups and their expression in the subsequent generations, which is utilized to plot the gene on the chromosome and the distance was expressed in centimorgans. But this is not used in the present day context because more efficient techniques have been evolved.
- (ii) Segregation of cell hybrids: The segregation of fused somatic cells can also be used in detection of gene. It can be utilized in higher organisms. The fusion of dissimilar cells can be brought about by inactivated Sendai virus. These fused cells have unstable karyotype and so a chromosome or its part may be lost, the loss of

chromosome leads to the loss of a specific function and there by a gene is denoted on the missing chromosome.

(iii) Use of molecular markers: Molecular markers are specialized compounds added to the medium, which indicates the presence or absence of a gene in the chromosome, which will ultimately produce the enzyme that will incorporate the compound. As for example, the gene for producing thymidine kinase when absent in an organism, makes it impossible for the organism to convert thymine to thymidylic acid. These organisms can grow in presence of toxic base analogue like bromo deoxyuridine in the medium containing thymidylic acid. In this way the gene for thymine kinase was denoted in chromosome 17 for human and genes for 14 other enzymes were denoted on separate chromosomes.

(iv) Restriction Fragment Length Polymorphism (RFLP): In recent years, RFLPs

have been used molecular genetic markers in higher organisms including man. RFLPs were revealed by the activity restriction endonucleases, used to digest genomic DNA, followed by hybridization with cDNA clones. This techniques is different in human from that of mice. Drosophila or that of plants. The segregation pattern of markers are studied with respect to reference families with known cell line and 59 such families have been maintained in Paris. The RFLP linkage map is produced with the help of computers with a software called program Mapmaker. The RFLP linkage maps should be studied along with morphological - and economic traits in plants,

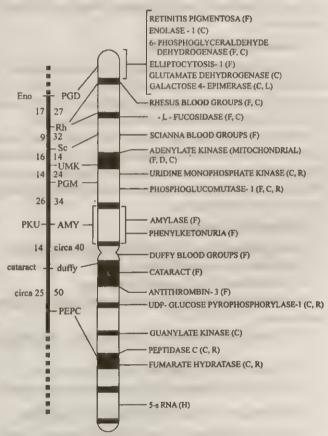


Fig. 14.16: Map of chromosome 1 of human genome showing the respective genes and their functions.

so that they can be used successfully in plant breeding.

14.6.6. TOTIPOTENCY OF CELLS:

The ability of a single cell to regenerate the entire organism is known as totipotency. It was originally believed that the ability is only limited to plants, but later on the animal cells were also shown to be totipotent.

Totipotency in plant cells :

In the period between 1950-55, the principle of regeneration of an entire plant from a simple explant is by using the principle of totipotency. The explant was taken from toot, shoot or leaf tip and transferred aseptically to a nutrient medium, resulting in the formation of callus. The modification of auxin/kinetin in the callus led to the differentiation of root and shoot and the entire plant is regenerated. In general the menstematic cells have the highest power of totipotency, which is gradually reduced with the differentiation of permanent tissue, though some matured gymnosperm cells may be totipotent. In this way, a single epidermal cell of oil seed plants like rape-seed, sunflower can regenerate the entire plant. The totipotency of immatured pollen grains of angiosperms can be utilized to generate a haploid plant or sometimes they exhibit spontaneous fusion in culture to produce the diploid plant again. The totipotency of root cells of monocot plants like maize, wheat are utilized to produce the desired cell line culture.

Totipotency in animal cells:

A normal animal cells was believed to be non-totipotent because it shows excess of differentiation. But the zygote, formed by the fusion of spermatozoid and egg are totipotent, because they can regenerate the entire organism, though a differentiated skin cell, nerve cell or muscle cells are non-totipotent.

Wilmut in 1997, has shown that the 2n udder cell of sheep was totipotent, when allowed to grow in a ovum atmosphere. This has led to the development of the cloned sheep Dolly, in recent years, the cloned cancer cells injected into the cultured cells of the blastocyst of mice was found to be totipotent and this principle can be utilized in the generation of hybridoma.

Application of totipotency:

- (1) Production of root or shoot up cultures in monocot.
- (ii) Production of haploid plants.
- (iii) Production of cell suspension culture
- (iv) Rapid propagation of certain plants, which normally takes long time for seed germination.
- (v) Production of cloned cell lines meant for the production of vaccine, hormones etc.
 - (vi) Production of cancer cell lines and hybridoma.
 - (vii) (loning of manimal like sheep, cattles and possibly man.

14.6.7. PLANT CELL AND TISSUE CULTURE:

In plants cell and tissue culture started in 1900 with the first ever attempt to culture plant cells in artificial medium. Haberlandt in 1902 for the first time was successful in culturing embryos from vegetative cells in artificial medium. Between 1951 and 1960 Miller et al successfully denoted the role of cytokinin in tissue culture. Skoog and Miller (1960) effectively used auxin and cytokinin in the shoot and root induction in callus culture of tobacco. In the 1970, protoplast isolation, culture and regeneration were brought about. In the 1980, somaclonal variation and recombinant DNA technology was introduced in tissue culture.

(a) Culture Medium: The medium for plant cell culture was introduced by Murashige and Skoog (1962), the major constituents include inorganic nutrients, trace elements, iron, vitamins, carbon source and plant growth regulators.

(b) Procedure for Tissue Culture:

(i) Sterilization of glassware: The glassware is boiled in 10% Na₃CO₄ solution for 2 hours, washed in tap water. It is then soaked in 30% nitric acid, dried and sterilized in an autoclave at 16 lb.p.s.i preessure for 1 hr. Alternately, the glasswares can be sterilized at 160°C in the hot air oven for 2 hours. The medium is sterilized in the autoclave at 16 lb p.s.i pressure for 20 minutes.

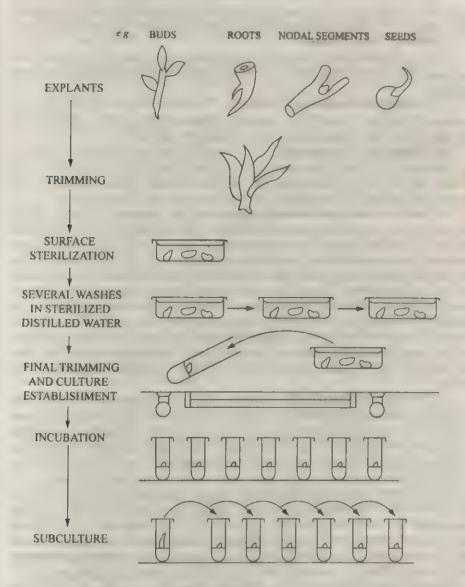


Fig. 14.17: Schematic Outline of Tissue-Culture procedure in plants

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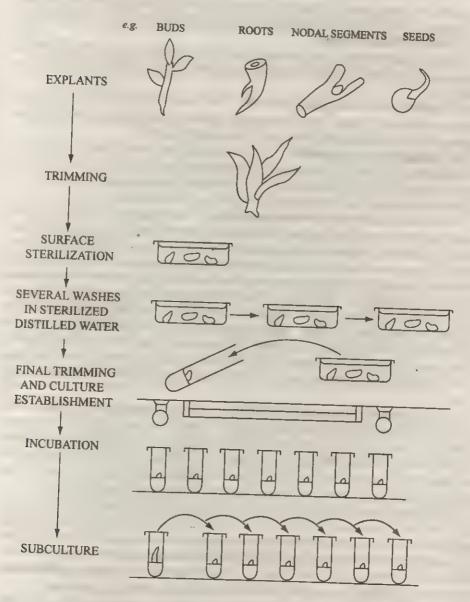


Fig. 14.17: Schematic Outline of Tissue-Culture procedure in plants.

(ii) Sterilization of Plant Material: Initially the plant material is cleaned with water and detergent. Then the explant is treated with 70% alcohol and washed with distilled water. Then it is sterilized with 20% chlorine water, 10% bleaching powder and 0.1% IIgCl₂. After sterilizing with these chemicals, the explants are then transferred to culture medium in aseptic condition in a laminar flow chamber.

(iii) Culture and Organogenesis: The explant proliferates into an undifferentiated mass of cells called callus, the callus tissue regenerates into an entire plant through

development of shoot or root by modifying the level of hormone.

The callus develops adventitive bipolar embryoids by changing the CO₂ concentrations or by adding polyamine, glycerol and GA₃. Artificial seeds are prepared in the laboratory by encapsulating somatic embroys with polymers like calcium alginate.

(c) Used of Tissue Culture:

(i) DNA amplification: The cultured plant tissue shows specific DNA synthesis and amplification. This DNA amplification helps in cell de-differentiation and induction of tumor.

(ii) Production of Androgenic haploids: The culture of pollen grains produces androgenic haploid culture. These androgenic haploids help in genetic stabilization,

development of pure lines and isolation of auxotrophic mutants.

(iii) Production of monopolids: The monoploids are sporophytes with gametic chromosomes, they can be generated by the culture of either the male gamete or the female gamete. They are the easiest way of achieving homozygosis, they help us to understand mutation frequency or can be the unique material for gene transfer.

- (iv) Isolation, culture and fusion of protoplasts: The plant protoplasts are produced by stripping of the cell wall and cell membrane either mechanically or by enzymatic means. Its viability depends on the physiological state of the cell, pH, purity of the enzyme. These protoplasts are cultured in medium containing sugar, amino acids, casein hydrolysate, coconut water and inorganic acids in the form of suspension culture, droplet culture or microculture. The fusion of protoplasts involves fusion of two separate genomes, which can be related or unrelated, even non-compatible strains can also be fused by this technique. It can be either spontaneous or can be induced by physical or chemical means and it produces a cybrid. The protoplast fusion can produce variation within plants, partial gene transfer in a cybrid leading to disease resistance or tolerance to salt stress. The cytoplasmic gene for male sterility can also be transferred in this process.
- (v) Induction of Somaclonal variation: The term Somaclonal variation was coined by Larkin and Scowcroft, that means all types of variations obtained in plants produced by tissue culture. The cause of this variation is due to transferable elements of the cytoplasm, natural mutagenesis or due to cultural variation. These variations not only produces different individual but it can also lead to the reduction of deleterious changes in plant cells. It can also be used in the production of transgenic plants.
- (vi) Micropropagation: The process by which an explant of specific plant is grown in a callus culture and multiple embroys are initiated. These embroys are either directly propagated or it can be transformed to artificial seeds by covering with calcium alginate e.g. celery. Alternately, a plant can be propagated by multiple shoot propagation where shoot tips are grown in specialized low salt medium and they develop into protocorms which are cut off and regenerated into whole plant e.g. Carnation, Gladiolus.

Animal Tissue Culture: The animal tissue culture was initiated in 1907, but successful culture of mammalian cell lines was possible only during the late 70's. The

primary problem of animal tissue was that they do not have totipotency like plant cells, i.e., they do not have regenerative power like plant cells. Moreover the cells or cell aggregates when separated from each other lose their membrane integrity and so cannot survive in that state. In recent years, animal tissue culture has been utilized in the production of proteins of higher therapeutic value and monoclonal antibodies.

(a) Cell isolation and culture: The cells are isolated by mechanical means by shaking with glass rods or by using enzymes. The cells isolated from specific animal cells are primary cell lines, these cells exhibit lag phase, log phase, reducing phase and stationary phase, they are diploid in nature, the cells produced from these primary cell lines have variable karyotype.

The medium used in animal cell culture contains all the nutrients like carbohydrate, amino acids, vitamins, mineral nutrients. It has pH of 7.0 to 7.3 and is isotonic to cytoplasm.

(c) Applications: The animal tissue culture has the following applications:

(i) Hybridoma production: Hybridoma is a hybrid cell line produced by the fusion of normal lymphocyte with a myeloma cell. It is used in the production of monoclonal antibodies.

(ii) Monoclonal Antibody: It is an antibody with a uniform structure specific for a single antigen site. (1) These antibodies are useful in immunological research. (2) Diagnosis of all energy. (3) Preparation of vaccine. (4) Preparation of probe for detecting a gene. (5) Presently monoclonal antibodies (MABs) are used to prevent rejection of transplanted kidney. (6) Detection of early pregnancy. (7) Detection particular type of leukaemias and lymphomas. (8) It may also be employed in the purification of interferon α2 derived from recombinant DNA technology.

(iii) Transgenic Animals: These animals are produced by modification and culture of germ cells using viral vectors or micro-injection. Though transgenic animals are not

very successful, but transgenic mice have been produced.

• Totipotency: The potential of a cell or a nucleus to pass through all stages of development and ultimately regenerating the entire organism is known as totipotency. It is commonly found in plant cells and hence this property is utilized in plant tissue culture. It is also observed in some specialized cells of higher animals called stem cells. Hence these cells can be an useful tool for regeneration of organs.

• Micropropagation: The method by which a plant can be propagated artificially by vegetative means is known as micro propagation. This process can

be of 2 types:

(i) Somatic Embryogenesis: Through this process, embryo formation is initiated in the callus culture, they can either be grown directly or can be isolated as artificial seeds by covering with calcium alginate. It was initiated by Stward (1963). These embryoids are successfully produced in case of Alfaalfa, carrot, celery.

(ii) Multiple Shoot production: The propagation of shoot tip is specialized medium, by which multiple shootlets are obtained in Begonia, Gladiolus or protocorms are produced in orchids, which regenerate into new plants. Thus many

plants are propagated in a short time.

14.6.8. ROLE OF PLANT HORMONES IN AGRICULTURE AND HORTICULTURE

The plant hormones are largely used for the betterment of crops and agricultural productivity. These hormones may be both natural or artificial in nature. The major roles are as follows .

[A] On Vegetative structure:

[1] Initiation of Roats in cuttings: Cutting is a very common method of vegetative propagation used in flowering plants like rose, chinarose. Treatment of IAA, IBA after cutting, induces root initiation.

[2] Control of weeds: Plant hormones like 2, 4-D and 2, 4, 5-Trichloro phenoxyacetic acid are sprayed on crop fields for the destruction of herbaceous weed plants in

the form of herbicides.

[3] Control of Budding: The emergence of adventitious buds in potato tubers is prevented by auxin treatment. Thus by preventing sprouting, potato tubers can be stored for longer time.

[4] Healing of Wounds: The mechanical damages or wounds in a plant body can cause entry of various pathogens. Hence healing of these wounds by the formation of

callus tissue is very important and it is induced by compounds like IAA.

[5] Control of Cambial activity: The secondary growth in plants is due to the formation of cambial ring formed by the fusion of fascicular and inter-fascicular cambium. The inter-fascicular cambium is induced by kinetin. Later those cambial rings develop into annual rings, formed during one year, maximum growth is observed during spring (early wood) and minimum during winter (late wood). The cambial activity

is promoted during secondary growth due to treatment of IAA.

[6] Control of Abscission: Abscission means falling of leaves, fruits etc., from the plant body. The abscission layer is formed at the petiole or at the fruit stalk, it is marked with the dissolution of middle lamella, which reduces the mechanical strength of the leaf stalk or fruit stalk and resulting in early falling of leaves or fruits. Hormones like abscisic acid promotes the formation of abscission layer but hormones like 2, 4 -D, N.A.A delay the formation of abscission layer and thus prevent premature leaf or fruit fall.

[7] Control of Senescence: The metabolic activity of a plant gradually reduces with age and this is marked with chlorosis and other degenerative changes, the entire process is referred to as senescence. Hormone like abscisic acid promotes senescence, while cytokinin delays the process or senescence (Richmond and Lang's effect).

[8] Control of Morphogenesis: The undifferentiated growth of a plant cell in a nutrient medium is termed as callus. The appearance of specific plant organs like root, stem depends on the perfect balance of plant hormones. High auxin and low kinetin initiate rooting but low auxin and high kinetin content promote the development of adventitious buds.

[B] On Reproductive structure:

[9] Control of Flower and Fruit Development: Hormones can directly be used in horticultural practice like thinning of blossoms by which flowers of the inflorescence are destroyed and thus the number of fruits can be regulated.

[10] Initiation of Flowering: The process of flowering is a complex process mediated by hormones. On one hand gibberellin can modify apical bud to floral bud and induce flowering, while NAA, 2, 4-D stimulates the growth of floral buds as in pineapple.

[11] Control of Fruit growth and maturation: Plant hormones like IBA can

effectively induce maturation of fruits and increase of their size. e.g., tomato.

[12] Control of Parthenocarpic Fruit development: The production of seedless fruits or parthenocarpic fruits can be induced in grapes, squash, tomato due to treatment of IAA or IBA.

14.6.9. DIFFERENCES IN THE ACTIVITY OF PLANT HORMONES: [A] Auxin, Gibberellin and Cytokinin:

Points of Differences		Auxin		Gibberellin		Cytokinin
[a] Occurrence:	[1]	Mostly occurs in the apical meristems.	[1]	Mostly in the germinating seeds and cotyledons.	[1]	In yeast, endosperm tissue and also apical meristem.
[b] Chemical Nature:	[2]	Organic acid contain- ing Indole rings.	[2]	Terpeniod organic acid.	[2]	Modified Adenine with an amino group.
	[3]	They may be nitrogenous, IAA or non-nitrogenous in nature (Auxin A and B)	[3]	Nitrogen free compound.	[3]	Nitrogenous compounds.
[c] Transport :	[4]	Transport is basipetal or polar in nature.	[4]	Transported both in upward and downward directions.	[4]	Transported in all directions and can remain active even at the site of synthesis.
[d] Functions:	[5]	Active role in cell division.	[5]	No role in cell division.	[5]	Plays active role in cell division.
	[6]	Control tropic movement.	[6]	No role în tropic movement.	[6]	No role in tropic movement.
	[7]	Prevents premature leaf and fruit fall.	[7]	No such role.	[7]	No such role.
	[8]	Does not control dormancy of seeds.	[8]	Reduces dormancy and initiates germination.	[8]	It also stimulates germnations of seed.
	[9]	It causes apical growth by apical dominance.	[9]	No role in apical dominance.	[9]	It counteracts apical dominance and initiates branching.
	[10]	Promotes adventitious root production at the cut end.	[10]	Inhibits adventitious root production after cutting.	[10]	Initiates adventitious roots from cut ends.
	[11]	No role in senescence.	[11]	No role in senescence.	[11]	Delays senescence.

[B] Auxin and Gibberellin:

Points of Differences	Auxin	Gibberellin	
[a] Occurrence:	[1] Occurs at the apical menstems.	[1] Occurs in the germinating seeds and cotyledons.	
[b] Transport:	[2] Transport is polar or basipetal in nature.	[2] Transported in all directions.	
[c] Chemical Nature :	[3] Organic acid with Indole ring, can be nitrogenous or non-nitrogenous in nature.	[3] Terpenoid organic acid, nitrogenous in nature.	
	 [4] Regulates tropic movement. [5] Promotes growth of apical bud and retards growth of axillary bud. [6] No role in breaking dormancy. 	 [4] No effect on tropic movement. [5] Promotes growth of axillary buds. [6] Breaks dormancy of seeds by synthesis of specific enzymes. 	
[d] Function:	[7] Promotes intiation of root after cutting [8] Stops abscission of leaves.	[7] Inhibits root initiation after cutting. [8] No role in checking abscission.	

[C] Auxin and Cytokinin:

Points of Differences	Auxin	Cytokinins
[a] Occurrence:	[1] At the apical meristems.	[1] Occurs at the meristems and endosperms.
[b] Transport:	[2] Transport is polar.	[2] Transport in all directions and even remains active at the site of synthesis.
[c] Chemical Nature :	[3] Organic acid with Indole ring, can be both nitrogenous or non-nitrogenous in nature.	[3] Modified Adenine with amino group.
[d] Functions;	[4] Controls tropic movement. [5] Stops abscission. [6] Does not stimulate seed germination [7] Promotes apical growth by apical dominance. [8] No role in preventing senescence.	 [4] No role in tropic movement. [5] No role in stopping abscission. [6] Stimulates seed germination. [7] Initiates branching by counteracting apical dominance. [8] Delays senescence.

[D] Gibberellins and Cytokinins:

Points of Differences	Gibberellins	Cytokinins
[a] Occurrence: [b] Chemical Nature: [c] Functions:	 Occurs in the germinating seeds and cotyledons. They are terpenoid organic acid without nitrogen. No role in cell division. Inhibits adventitious root initiation. Causes elongation of internode. No role in senescence. 	 [1] Occurs in the endosperm and also in the apical meristem. [2] Modified adenine with amino group. [3] Play active role in cell division. [4] Initiates adventitious roots. [5] No such role. [6] Delays senescence.

14.6.10. Biomedical Engineering:

[A] Diagnostic Instruments:

[a] Electrocardiograph:

ECG or electrocardiogram is the graphical representation of the electrical activity of heart recorded by placing electrodes on the body surface. The machine in which electrocardiogram is recorded is known as **electro cardiograph**. ECG is actually the record of electric discharges associated with the activity of heart and not the record of contraction and relaxation of cardiac muscles. Since the electrical stimuli generated from the different chambers of the heart are not transmitted equally in all directions, the record, will vary accarding to the parts of the body. **Waller** (1887) first recorded the electrocardiogram, but **Einthoven**(1903) explained the device and is known as the **'Father of electrocardiography.'**

Mechanism. The inner surface of cardiac muscles remain in negative state (-90 mV) because of more exit of Na* ions. During muscle contraction, an action potential is produced, so the Na* ions move inside making the interior positive, this is known as depolarisation. This creates a dipole field between the polarised and depolarised parts of muscle fibre. This contraction wave and dipole field travels at the rate of Im/sec. But after half a seond, repolarisation of the cardiac muscle takes place to bring them back to polarised state. This also causes the movement of dipole field, but with reversed polarity.

These dipole movement generates individual electrical vectors, summed up as a

resultant vector. As the contraction spreads in the cardiac muscle in a regular temporal sequence, the resultant vector varies in magnitude and direction.

An ECG shows six consecutive waves denoted by P,Q,R,S,T, and U. The P wave represents atrial depolarisation, QRS complex represents ventricular depolarisation, T wave represents ventricular repolarisation and U wave represents atrial repolarisation. The Uwave is often absent because it is superimposed by the ORST waves. Any variation from its normal pattern indicates some pathological conditions of the heart.

Uses:

- (i) It gives the accurate information about the functioning of auricles and ventricles.
- hypertrophy (ii) It indicates the (overgrowth) in the ventricles.
 - in 3 standard leads. (iii) It indicates heart attack, fibrillation or heart block.
- (b) Electro encephalograph: The rhythmic potential changes generated by millions of neurones of brain are recorded with the help of electrodes placed on the scalp and is called electro encephalogram (EEG) and the recording device is called electro encephalograph. Essentially the process is similar to electro cardigram, but the method of generation of electrical stimulus is largely unknown unlike that generated in ECG.

Mechanism: The inside surface of the membrane of neurone is negatively charged (-70my). This state is polarized state. Due to the reception of the stimulus, the exitatory potential is generated and more Na+ ion influx takes place across the membrane, the depolarization of the membrane takes place, this is inhibited by the inhibitory potential. Shortly after depolarization, repolarization takes place again.

- (i) It detects any sort of junctional irregularity of the brain, though a conclusive diagnosis may not be possible always.
 - (ii) It may be used in detecting neurological disorder.
- (ii) It may be used in brain fingerprinting, which is a latest technique for detecting criminals. Here the incident is repeated in front of 3 persons, one suspect, one witness and one not related to this incident and the brain waves show distinct variations.

But the potential generated from the brain neurone are weak, they gradually become feeble with the increase of distance from their point of origin, as a result of which EEG has been replaced by SQUID (Super Conducting Quantam Interference Device), which can detect the weaker magnetic fields of the brain and the technique is known as "Magneto cephalography" or MET. The use of CT scan also can detect any sort of irregularity of the brain including tumor, haemorrhage etc.

(c) Autoanalyzer (Automatic Analysis by continuous flow):

The principle of autoanalyzer is to analyse a sample continually under controlled

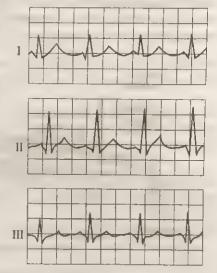


Fig. 14.18: Normal ECG curves

condition, the liquid sample here is advanced with a roller pump, through a long plastic tube, the reagent solutions are mixed through converging tubes. The sample is dialyzed through converging tubes. The sample is dialyzed through a special memberane and photometric analysis is carried out.

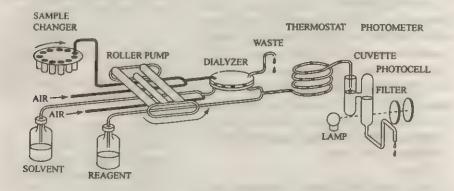


Fig. 14.19: Working principle of a autoanalyger.

Since the samples from different patients are passed in successively, there is a possibility of contamination, so air bubbles are introduced in the tubing system, which will break the liquid column into smaller segments.

Advantages:

- (i) The operational cost is low.
- (ii) The process is compatible with any type of photometry like absorption, photometry, flame photometry.

At the sametime, there are some disadvantages of this system:

- (i) The system is not full proof against contamination.
- (ii) The dialysis may not be carried out in equilibrium because of the paucity of time.
 - (iii) The acute or urgent samples cannot be inserted easily.

In spite of these demerits, this method is ideal for identification or testing of liquid samples and is followed in 80% of biochemical laboratories.

[B] Imaging Instruments:

(a) Ultra sonography: Ultra sonography (USG) is an imaging method by using ultrasound. This sound is beyond the scope of human hearing, it is produced by applying electrical potential to crystals of certain compounds like lead zirconate. This phenomenon is termed as piezoelectric effect. The vibration generated from lead zirconate is termed as ultrasound. But this sound can only pass through a medium and when introduced through a homogeneous tissue, they pass unimpeded, till they meet another tissue or organ. Then it is reflected and received back by the same crystal, converted to electrical signal and shown in an oscilloscope screen as a deflection from the base line.

Uses:

- (i) Used to denote the position of the foetus.
- (ii) Any sort of tumor or enlargement in any organ of the upper and the lower abdomen.

- (iii) In echo cardiogram.
- (iv) To denote the renal ar gall bladder stone.
- (v) Ulceration in the stomach or duodenum.
- (vi) Any irregularities of liver.

It is environmentally safe and the USG of a pregnant woman does not cause harm to the foetus. But it cannot pass through vacuum, so it is less penetrative than electromagnetic waves.

(b) C.T. Scan: The full form of CT scan is computed tomographic scan, it was invented by G. Hounsfield (1972), who was later awarded Nobel prize in 1979. Initially the machine was used only for intra cranial images but later the machine was developed in order to scan the entire body.

The first ever CT scan machine was installed at the **Atkinson Mosby's** hospital in London in 1972, but the general purpose scanner was installed at the **Northwick Park** Hospital in USA in 1975.

The principle of CT rcan is to pass X ray through the organ and then instead of recording it on a photographic plate, it is reconstructed with the help of a computer.

Uses:

- (i) Detection of irregularities in brain including haemorrhagic points.
- (ii) Detection of diseases of spinal cord.
- (iii) Study of visceral organs, abdomen.
- (iv) Benign and malignant tumors.
- (v) To determine the feasibility of surgery and results of treatment.
- (c) PET Scan: The full form is Position Emission Tomographic Scan. It is much advanced than CT Scan because it provides quantitative information on the metabolic and physiological processes of the tissues and organs.

Principle: The positron emitting radio isotopes like ¹¹C, ¹³N, ¹⁵O obtained from cyclotron are used in this technique. These radio isotopes are incorporated into various compounds like glucose, amino acids and then the patient takes in these compounds. As a result, these compounds are distributed in the different organs of human body. The three dimensional images are taken by PET cameras and the images are reconstructed by computer.

Uses:

- (i) Measurement of different parameters of brain.
- (ii) Blood flow in vital organs.
- (iii) Metabolic rates of different food components.
- (iv) Functional aspects of different parts of brain like the colour processing centres of the visual cortex of human brain.
- (d) X Ray: It is a high energy electro magnetic wave varying in length from 0.05—100Å. They are produced by bomdarding a target (anticathode) in a vacuum tube with high velocity electrons. They have the ability to penetrate most of the substances and also can act on photagraphic plate, hence can be used in the study of internal organs. It was discovered by W.K.Roentgen. in 8th November, 1895.

Uses:

- (i) Study of internal organs.
- (ii) Study of fractures of different kinds.
- (iii) Change in organ structure due to varied etiology.

tive I declare of var o's orenes like aim?

- (v) Position of the foctus.
- (vi) Study of different chemical crystals
- expressed of the cleaner emanano naples

Reported Non-exposure may be funzerous because it pro-fuces the harmful effects of ionizing radiation

It can also capa some retition or demarks. It can also cause harm to the foctus-

(e) Fluoroscopy: The technique was in traced shortly iffer the fiscovery of V-ray. The technique involve—technique or an with X-ray after stamment with a fluoroscent disc. But in this case—i continuous beam of X-ray is used, so it is able to renerate dynamic images.

Principle: The technique involves exposure of an organito is home of X ray, the emerging X rays from the organ is passed through an invasor intensifier. The image is registered on a flaore scent series is from let to profess a ratio over image, the fluorescence is mainfield by passing the electrons through a victum.

lises:

- (i) Detection of spinal injury.
- on the adapties within the stomach in Eintestine can be detected
- (iii) Detection of intestinal movement
- (iv) Detection of blood flow within the coronary arteries by coronary catheterization and the use of specific dye.

The technique also involves the hazards of exposure to X ray, the use of dve may cause hypersensitivity or rigor in the patient. The vacuum tube must be intact, other wise the leakage of X ray cannot be ruled out.

(f) Endoscopy: The technique was intiated by B. Hirschowitz (1957) in Michigan University, USA. It actually involves the method of taking photographs of the internal visceral organs.

Principle: The principle involves the use of 2 fibre optic lines, the first one is a light fibre that carries the light into the organ of the cavity, the second one is an image fibre, that brings back the image back to the lens. There is a provision of a third part, which can be used for immor surpury, administration of drugs. The set up works ideally with a video camera.

tises:

- (1) It is used to study abscesses, haemorrhagic points in the internal organ, liver cirrohosis, bronchitis.
 - (ii) It is used to carry out biopsies.
 - (iii) Laparoscopic surgery of gall stone.
 - (iv) Detection of tumors and inflammations.
 - (v) Surgery for acute prostitis.

Types: On the basis of organ studied, endoscopy can be classified into the following types:

- (i) Arthroscopy-Joints.
- (ii) Bronchoscopy-Bronchus.
- (iii) Colonoscopy-Colon.
- (iv) Colposcopy-Cervix.
- (v) Cystoscopy-Urmary Bladder.

- (v1) Endoscopic Retrograde cholc Pancreatography (ERCP) Gall Bladder and Pancreas
 - (vii) Gastroscopy-Gastro-Intestinal tract.
 - (viii) Laryngoscopy-Larynx.
 - (ix) Proctoscopy-Rectum.
 - (x) Thoracoscopy-Thoracic cavity.

In general endoscopic surgery with the help of key holes are mainly called laparoscopic surgery, which are very common these days for pall bladder, prostate glands etc. The recovery of the patient is fast and no medication is required.

(g) MR1: The full form is magetic resonance imaging and is based on the phenomenon known as nuclear magnetic resonance (NMR). It is denoted by Block and Purcell in 1946 and was awarded Noble prize in Physics in 1982. Further development was achieved by F. Odeblod in 1960 in order to study the internal tissues like blood, mucus, myometrium of man. Lauterbur and Mansfield developed the technique further in 1970s and were awarded Nobel prize for their commendable work in 2003.

Principle: It is a new non-invasive method of mapping the internal structure of the body without using the ionising radiation, so the health hazard is minimized. It employs the radio frequency radiation in presence of controlled magnetic field, in order to produce high quality cross sectional images of the body in any plane. The technique actually portrays the distribution of hydrogen ions and their motion in cellular fluids. It generates the images of soft tissue like CT scan, MRI has an additional advantage of its ability to manipulate the contrast between two different tissues that detects the pathological changes in a tissue. It has been gradually established that MRI is a more efficient and sensitive technique than CT scan.

Uses :

- (i) Images of the brain at any plane to detect irregularities in blood flow, tumor etc.
- (ii) Circulation problems in different internal tissues
- (iii) Pathological conditions of cervical mucus, myometrium
- (iv) Detection of retinal circulation problems.
- (C) Therapeutic Instruments:
- (a) Laser therapy: I asers are high energy particles of light, which are amplified by stimulated emission of radiation. Lasers can vary on the basis of its source and they are argon laser, neon laser, carbon di-oxide laser etc. These lasers have a severe burning effect on human tissue, so cold laser therapy is carried out to reduce that effect.

Principle: The laser beam is focussed on the affected area (cancer cells) to burn it off. This is done with high degree of accuracy and precision so that the surrounding areas are not affected.

Uses :

- (i) Treatment of tumors in the retina, brain and other parts of human body
- (ii) Destruction of renal stone.
- (iii) Removal of cataract during phaco emulsification, surgury
- (b) **Blood Dialyzer**: This device is also called artificial kidney because when the kidney of a patient is damaged or not working properly, this device is used to remove tirea and other waste product from the blood of the patient, this method is termed as **haemodialysis**.

Principle: The device works on the principle of separating certain substances from the blood by the use a selectively permeable membrane. The pores of thes membranes allow the waste material to pass through, but retains back useful materials.

The radial artery of the patient is connected to the machine with the help of a tube. Blood from the artery is pumped into the tube and ultimately into the dialyzer. The dialyzer contains a cellophane tube filled with dialysis fluid containing same amount of electrolyte and nutrient as the normal plasma, but is devoid of waste products. The pores of the cellophane tube do not allow the movement of blood cells and proteins into the fluid but it allows urea, ammonia and other waste products into the dialysis tube.

Since the dialysis fluid contains same concentration of glucose, amino acids and electrolytes, these substances from blood cannot pass into the dialysis fluid. In this way the blood gradually gets freed from urea, uric acid, aminomia, creatinine and other waste products. After purification, the blood is returned back to the patient's body via the radial vein.

Uses: (1) The device is used to purify blood from urea in patients with acute or chronic renal failure due to various reason.

This process cannot be carried out without the active participation of the patient. It is also not suitable in patients with very low blood pressure, severe anaemia or high blood sugar.

(c) Pacemaker: A natural pacemaker is the SA Node, which generates electrical stimulus to maintain the heart rate. Due to Heart block or Stoke Adams syndrome, this rhythmicity is lost and the person may become unconscious repeatedly and mortality may be 50%. He is then fitted with an artificial battery operated electrical pulse generator called artificial pacemaker.

Principle: The pacemaker is directly connected to the heart via cables and the electrical connection is maintained via electrodes, which are directly in contact with the cardiac muscles. Presently the pacemaker is placed below the skin in a pocket just below the clavicle. The cable is threaded through a vein in the shoulder, passed via superior venacava, through the right atrium, until the electrode is at the tip of the right ventricle. The position of the pacemaker can be detected either by fluorscopic method or by connecting to an ECG unit. In order to correct atrial activity, it is not required to open the thoracic cavity, but the electrode is inserted into the jugular fossa with the help of a passage created by mediastinoscope in the loose connective tissue surrounding the atria.

Types: About 70% of the pacemakers are demand pacemakers responsible for ventricular synchronization, they cannot bring about atrial and ventricular synchronization.

The rest is advanced pacemakers, which can synchronize atrial activity by placing the electrode close to dorsal wall of the atria.

Interference: The pacemakers may show electromagnetic interference with electric shaver, car ignition and microwaves. But the new generation pacemakers are provided with high grade filters and amplifier input circuit, that reduces this problem.

(d) Heart Lung Machine:

The device which runs the heart and lung artificially at the time of open heart surgery is known as the heart lung machine.

This machine is also called **pump oxygenatar**. It was denoted by **Jolen Gibbon** in 1937 in cat, used in man in 1953.

Principle: The machine draws off blood from the vein and after oxygenation in a membrane or film oxygenator, it is returned back to the arterial system. The contraction of the heart is temporarily stopped by running a solution of potassium citrate through the coronary vessels.

Uses: It is mainly used in coronary bye pass surgery, so that the repairing work of the heart can be done smoothly without blocking the vision by blood.

14.7. Matters to Recollect

- Biofertilizers include nitrogen fixing organisms.
- They are broadly classified as bacteria, cyanobacteria and mycorrhizae.
- Bacteria can be free living, loosely associated and symbiotic in nature
- Cyanobacteria can be free living and symbiotic in nature.
- Mycorrhizae can be either ectotrophic or endotrophic in nature.
- Insecticide literally means killer of insects. Herbicides are killers of weed; fungicides are killers of fungus; nematicides are killers of nematode. All these are included in the term of pesticide. Hence pesticide is denoting a killer of pests. Thus pesticides are used for controlling, preventing, destroying and repelling any pest.
- Among the pesticides, the insecticide is used widely. In most instances insecticides are chemicals. These chemicals are toxic to the insect pests and they are mainly classified in the three ways, namely, stomach poison, contact poison and fumigants.
- Pesticides can create serious problems not only in crops but also they cause air and water pollution. They are doing harmful effects on beneficial insects. Toxicity of insecticides can cause harmful effect to fish and wild life population in the surrounding areas. Toxicity of pesticides can cause health hazards to man.
- Biological control is the use of enemies (predators, parasites *etc.*) to control the pest species.
- Although there have been some successes in biological control but its potential has not been fully developed for most crops.
- Man has brought the few kinds other species under domestication of plants and animals. How and when most of our important animals and plants were domesticated are still matters of controversy. Dog is generally considered to be the oldest of the domesticates. But when and where the dog first domesticated are still matters of controversy.
- A species is endangered when it is facing a very high risk of extinction in the wild in the near future. Declining of wild species are caused by indiscriminate killing, destruction of habitat, introduction of exotic species and also the international trade. Hence all efforts should be given for preservation of endangered species.
- Red Data Book gives information about the threatened species as well as the urgency of their conservation problems.
- Green Data Book provides information about rare plant communities which are in need of conservation and protection.

- The product of the silk moth is the silk. This silk is known as 'queen of fibres'. Bulk of the silk is utilized in preparing silk clothes in India.
 - The main product of bee is the honey which is extracted from bee's hive.
 - Lac insect secretes resinous substance which covers the male and female insect. This resinous substance, has great commercial value, as it is utilised in different industries.
- Biotechnology involves technological advancement involving micro-organisms.
- Biotechnology mainly involves recombinant DNA technology, tissue culture, enzymes and fermentation products.
- Cloning involves replication of a cell by incorporation of a foreign DNA.
- Benefits of biotechnology involves production of transgenic microbes, plants and animals.
- Sperm and ova banks store sperm and ova (collected from males and females) at a very low temperature (i.e. in frozen state) for future use.
- Sperm stored in sperm banks may be used for artificial insemination or *in vitro* fertilization.
- Ova stored in ova banks may be used for in vitro fertilization.
- A baby born by in vitro fertilization is commonly called test tube baby.
- A woman who lends her womb and bears a child for another woman is called surrogate mother.
- DNA fingerprinting involves identification of an individual on the basis of DNA pattern.
- Gene mapping is carried out by linkage studies, segregation of hybrids, use of molecular markers and also by the use of restriction fragment length polymorphism.
- Plant tissue culture is regeneration of the entire plant from an explant grown aseptically in a nutrient medium.
- Animal tissue culture is mainly used in the production of hybridroma and monoclonal antibody.
- Plant cells unlike animal cells exhibit totipotency.
- Micropropogation either involves somatic embryogenesis or multiple shoot production.
- Plant hormones are broadly used in agriculture both in the development of reproductive structure as well as vegetative structures.
- Auxin, gibberellin and cytokinin are the three major plant hormones used in agricultural developement.
- Biomedical engineering deals with the application of engineering technology in medicine for diagonostic and therapeutic purposes.
- ECG (electrocardiogram) is the graphical record of the electrical activities of heart obtained by placing electrodes on body surface.
- An ECG shows P, Q, R, S, T and U waves.
- EEG (electroencephalogram) is the graphical record of the electrical activities of brain obtained by placing electrodes on scalp surface.
- EEG waves may be of four major types-alpha, beta, theta and delta.

- Auto analyzer is a computer-controlled equipment used for biochemical analysis of large number of body fluid samples within a short time.
- USG, CT scan, X-ray, Fluoroscopy, Endoscopy and MRI are common methods for imaging of internal organs.
- USG (ultrasonography) is an imaging method using ultrasound, which gives computer aided video images of internal structures showing their location, size, shape, texture etc.
- CT scan (computed tomographic scan) is an imaging device which gives a complete series of pictures showing slices through the body at different planes.
- CT scan is also called CAT scan (computerised axial tomographic scan).
- X-ray or ordinary radiography gives detailed images of dense parts of the body like bones.
- Fluoroscopy is an imaging device which gives time-varying X-ray images on a fluorescent screen for visual examination of live dynamic events.
- Endoscopy is a device for viewing and monitoring (carrying out minor surgery) of internal organs of the body including inside of the hollow viscera by inserting fine tubes (containg cables) to the target site.
- MRI (magnetic resonance imaging) is an imaging device based on nuclear magnetic images of the body and is mainly used to detect small lesions in brain and spinal cord.
- Laser therapy is a surgical pocedure, in which a laser beam is used to remove (burn off or dissolve) tumors, blood clots or stones from deeper parts of tissues like brain, eye, kidney etc.
- Dializer is an equipment known as artificial kidney, which is used to remove urea and other waste matters from blood in cases of renal failure.
- Artificial pace maker is an electronic device used to maintain rhythmicity of heart in patients with heart block.
- Heart-lung machine is a device which artificially maintains circulation and respiration during open heart surgery (coronary artery by-pass surgery).

14.8. Summary:

Biofertilizers are different from organic manure because they include a group of micro-organisms which enrich the soil with nitrogen unlike manure, which is only semi-decomposed or decomposed organic matter. Biofertilizers can be bacteria, cyanobacteria and mycorrhizae. The bacteria, can be free living, lossely associated with host plant or symbiotic in nature. Cyanobacteria can be either free living or symbiotic in nature. Mycorrhizal fungi grow in association with roots of higher plant that can be either ectotrophic or endotrophic in rature.

Agricultural pests, household pests and garden pests can be controlled by pesticides. Insecticides are particular kinds of pesticides for killing insects. Insecticides and other pesticides are some of the most important chemicals used for the well being of human society. They are indispensible in maintaining high-levels of health, nutrition and surroundings.

Pesticides can create serious problems to crops as well as kill the soil organisms. Moreover pesticides create air and water pollution; also cause health hazards to man and cause detrimental effects on beneficial insects, natural balance, ecological cycles *etc*.

Biological control is the use of enemies (may be predators, parasites *etc.*) to control pest species. Biological control is the living weapon over chemical control. This method is the modern method of pest control. Natural enemies are functioning as predators, parasites or pathogens.

Although there have been some outstanding successes through biological control but there are some hazards also, such as polyphagous predator does not always suppress a growing pest population or the host searching capacity may be highly reduced by weather and other factors.

Man has brought the few kinds of animals and plants under domestication. Thus the people of the world depends on a small group of cereals, specially rice, wheat and maize. These cereals are responsible high yeild of food. They are easily transported and stored. In the ancient civilizations man had domesticated few animals, these domesticated animals are neither utilized as food nor as a source of power. Domesticated animals and plants became biologically different from their wild ancestors.

The conservation of endangered wild species are very important due to the maintenance of balance in nature, for breeding programmes, for evolutionary continuity, for pollination, for aesthetic value etc. Hence scientists of the world have developed a comprehensive world conservation strategy for the proper use of resources. Strategies are— (i) all efforts should be given for preservation of endangered species (ii) good management of land and water uses (iii) different varieties of food crops, timber trees, livestock etc., and their wild relatives should be preserved (specially the endangered species) (iv) habitats of the endangered species should be protected through some projects. (v) commodities of wild origin in the international trade are to be regulated by appropriate law.

Rearing of larvae is the main aspect of sericulture. Larvae need a healthy and an abundant growth of food plants. Larvae of *Bombyx mori* feed only on leaves of mulberry plant. So the mulberry worm is regarded as monophagous insect. Main product of silk-worm is the silk, which is utilized as garments in the human society. In India, mainly *Apis indica* is reared in wooden box, where honey is extracted without the damage of the hive. Lac is regarded as resinous substance, which is secreted by the members of lac insect. Female insect is producing more lac than the male one.

Biotechnology is the technological development involving microbes. The major domains of nucro-biology are recombinant DNA technology, tissue culture, products related to enzyme, protein, food and fermentation. Cloning is a phenomenon by which large number of identical cells are produced, Cloning involves isolation of a desired gene, cutting off the vector, incorporation of the gene into the vector to produce a chimeric DNA and incorporation of the chimeric DNA into a suitable host cell, its expression, followed by replication of the cell. The benefits of biotechnology includes the production of transgenic microbes capable of producing

greater amount of desirable products, production of transgenic plants with better potential in terms of nutritive quality, disease resistance, stress resistance etc. Animal transgenics are not very common.

Sperms and ova can be preserved in frozen state at a very low temperature (-195°C) in sperm and ova banks for future use. These are used in artificial insemination or *in vitro* fertilization. For *in vitro* fertilization, sperm and ova are collected from the husband and wife (or donors). Fresh or stored sperm and ovum are mixed in a petridish for fertilization and the embryo is transferred into the uterus of the mother. The embryo then grows upto the full term, and a child born in this way is called **test tube baby**. When the mother's uterus is absent or not suitable for child bearing, another woman's uterus is hired for rearing the embryo, such a woman who lends her uterus is called **surrogate mother**.

DNA fingerprinting is a technique by which a gene is amplified by polymerase chain reaction and separated in a gel medium. It is unique for an individual and hence can be used in the purpose of criminology or identifying a person. Gene mapping is a method of locating a gene on the chromosome. It can be brought about by the study of linkage groups, segregation of hybrids, use of molecular markers and restriction fragment length polymorphism. Plant cells can be grown in a better way in tissue culture because they are totipotent in nature. It involves the regeneration of the entire plant from a single explant and mainly used in micro propagation of plant. The process of micro propagation can either be shoot tip propagation or induction and propagation of somatic embryos. The animal tissue culture is mainly used for the purpose of hybridoma production and also production of monoclonal antibodies.

Plant hormones are broadly growth regulators used in the different fields of agriculture and horticulture. They are mainly of three types, *i.e.*, auxin, gibberellin and cytokinin. Auxin and its derivatives can be used in different purposes like prevention of sprouting of tuber, destruction of weed plants, prevention of loss of prematured fruits and leaves.

Application of engineering technology in the field of medicine for diagnosis and treatment of diseases is known as biomedical engineering. ECG and EEG help in diagnosis of cardiac and neural disorders. Autoanalyzers are used for biochemical analysis of body fluids very quickly. Various imaging techniques e.g., X-ray, USG, CT scan, MRI, fluoroscopy, endoscopy etc. are used to detect the abnormalities in internal organs. Endoscopy is also used in surgical treatments. Laser therapy is very useful for surgical removal of tumors, stones etc. from the internal organs without damaging other tissues. Dializer works as artificial kidney. Electronic pacemaker helps to maintain the cardiac rhythmicity in heart block patients. Heartlung machine is used to maintain circulation and respiration artificially, during open heart surgery.

14.9. Naming/Discovery/Discoverer

- [1] Charles Darwin and Francis Darwin (1880) first detected the presence of plant hormone like substances in canary grasses.
 - [2] Waller (1887) first recorded electrocardiogram.

[3] W. K. Roentgen (1895) invented X-ray.

[4] Haberlandt (1902) for the first time induced embryo culture in plants.

[5] E.S. Schafer (1910) proposed the term "autacoids" and divided them into two categories as hormones or stimulating agents and chalones or inhibiting agents.

[6] A. Paal. (1914) denoted that phytohormones are also produced from the tip of coleoptile.

[7] Soding (1925) first showed that phytohormones can induce tropic curvature.

[8] Kurosawa (1926) discovered gibberellin from Gibberella fujikuroi.

[9] Went (1928) discovered auxin from coleoptile tip of Avena.

[10] Kogl and Smith (1931) divided auxin into auxin A and auxin B.

[11] Huxley (1931) called it chemical regulators.

[12] Kogl and Kostermann (1934) first time denoted the structure of Heteroauxin or Indole Acetic Acid.

[13] Skoog and Thimann (1934) was first to denote the apical dominance of auxin.

[14] Yabuta (1935) gave the name 'gibberellin' after the fungus Gibberella fujikuroi,

[15] Zimmermann (1936) denoted the artificial hormone NAA.

[16] John Gibbon (1937) invented heart-lung machine.

[17] Skoog (1938) proved the polar translocation of auxin.

[18] Yabuta and Sumiki (1938) denoted two types of gibberellins viz., gibberellin A and gibberellin B.

[19] Avery, Mclood and McCarty (1940) denoted transformation in the bacterial cells for the first time.

[20] Mirov (1941) denoted auxin in the shoot tip of gymnosperms like Pinus.

[21] Bloch and Purcell (1946) discovered MRI.

[22] Thimann (1948) conclusively proved the role of auxin as a chemical messenger.

[23] Miller et.al. (1950) isolated kinetin from yeast t-RNA.

[24] Thimann (1951) showed the enzymatic action of auxin

[25] Stodola (1955) denoted two types of gibberellin as gibberellin A_1 and gibberellin A_2 .

[26] Lang (1956) showed the role of gibberellin in flowering of photosensitive plants.

[27] Richmond and Lang (1957) showed that kinetin treatment delays senescence in flowering plants and called it rejuvenating hormone.

[28] Hischowitz (1957) invented endoscopy.

[29] Willson and Thimann (1958) denoted that kinetin can counteract the apical dominance of auxin.

[30] Skoog and Miller (1960) showed that both auxin and gibberellin can induce morphogenesis in plant tissue culture.

[31] Wheeler (1960) denoted that germinating plant seeds are capable of producing gibberellin.

[32] Cross et. al. (1961) gave the structure for GA_v.

[33] Garton (1961) gave the biosynthetic pathway for auxin synthesis.

[34] Sarokin et. al. (1962) proved the role of kinetin in secondary growth.

[35] Murashige and Skoog (1962) developed the ideal medium for plant tissue culture.

[36] Steward (1963) induced the micro-propagation of shoot tip in plants.

[37] Wareing et. al. (1963) reported for the first time existance of abscisic acid in plants.

[38] Merryfield (1963) for the first time prepared a synthetic polypeptide.

[39] Letham (1964) reported zeatin from corn seed.

[40] Aiyer et. al. (1972) proved the utility of Aulosira fertilissima as the most successful nitrogen fixer in the paddy fields.

[41] Arber, Smith and Nathans (1972) devedoped the restriction endonuclease or genetic knife, used for cutting DNA fragments.

[42] G. Hounsfield (1972) invented CT scan.

[43] Dobreiner (1975) showed the increase in the yield of maize crop due to the presence of nitrogen fixing bacteria Azospirıllum lipoferum in the rhizosphere.

[44] Ikakura (1977) for the first time assembled the genes for human somatostatin

and insulin.

[45] P. Steptoe and R. Edward (1978) discovered test tube baby.

[46] Dreyfus (1979) showed that the legume plant Sesbania rostrata can exhibit double symbiosis with Rhizobium in the root nodule and Aerorhizobium in the stem nodules.

[47] Mullis et. al. (1985) developed the technique for polymerase chain reaction.

[48] Jeffrey et. al. (1986) developed the technique of DNA fingerprinting.

[49] A.M. Chakraborty (1990) developed the oil eating superbug.

[50] Lalji Singh (1990) successfully performed DNA fingerprinting in India.

[51] A. Dutta et. al. (2001) produced the transgenic rice and potato as AmA rice and potato with better nutritional quality.

14.10. Answers to special Questions

[1] How manures are classified?

Ans. Manures are classified as farmyard manure, compost manure and green manure.

How biofertilizers are classified? [2]

Ans. They are clssified as bacteria, cyanobacteria and mycorrhizal fungi.

Name a loosely associated association. [3]

Ans. The loosely associated symbiotic association is also called associative mutualism. It is observed between maize and the rhizosphere bacteria Azospirillum lipoferum.

[4] Name a siderophore producing organism.

Ans. Pseudomonas putida.

[5] What is the function of leg haemoglobin?

Ans. It removes oxygen from the site of nitrogenase in the nodule of legume plant, helping in nitrogen fixation.

Name the most common free living cyanobacteria in the paddy field? [6] Ans. Aulosira fertilissima.

Why is Azolla grown in a paddy field? [7]

Ans. Azolla contains the symbiotic cyanobacteria Anabaena azollae, which serves the purpose of nitrogen fixation in the paddy fields.

- the Name a metorshizal fungue.
- [10] Mention Vother common perticules with their effect on perts

Ans. Three common pesticides are .

- (a) Acarmides Killers of tick and mite
- (11) Fungacides Killers of lungus

- [11] What do you understand by the term 'l'est Control' '

 Ans. of the control of the leaf to the control of th
- [12] Classify the insecticides on the basis of toxic effect of the insect post.

 Any Process are consisted in the process of the insect possess.

 (ii) Contact poisons and (iii) Furnigants.
- [13] What is lumigants? How it acts on pest? Cite one example

 Ans. For methods proceed that the could be considered as proceed to proceed the considered as a few three departments of the considered as a few three departments of the tracked section. Some procedure to the form of the considered as a few three departments of the considered as a few to the first of the considered as a few to the first of the considered as a few to the first of the considered as a few to the first of the considered as a few to the consection for the consection

Example of fumigant (March 1) remade

- [14] Now man is effected by pesticides?

 Any Performance and an initial desired for residue laden plant.

 Consequently the action is presiduely of pesticide in the milk latest daily coase Unimately than recent perforde there is an action for the man.
- [15] What is biological control? What are the agents of biological control?

 Ans. B ological control is the accordance, control post species.

 Natural chemical or a tents may function us profutors parameter or pathosons.
- What are cultigens, and inquilines of Give examples of inquilines.

 Ans Callas its 1p ands and forms to its fan, mais are to ether known is cultigens.

 After constructions a correctly deep newlidenvironment, associated of animals with quickly move to their the deeper lass men forming the are known as human inquilines.

 I compare the construction scorpions, lizards and rats.
- [17] What do you understand by endangered species? Cite an example.

 Ans. Vol. 1. In the cred when it is the new years to the risk of extinction in the wild in the near future.

Example: One horned Rhino

to All effects should be given for preservation of species specially that its earlier on the Habitats of the endangered species should be protected and

Lemonne ally valuable as well as useful plants and animals are to be preserved in the protected areas. (iv) Different varieties of food crops, timber trees, law dock of and their wild relatives should be preserved and special priority should be given to threatened species.

[19] What is Red Data Book? Give examples of threatened species in India?

Ans, Wild species that are facing the risk of extinction are enlisted in a book known as Red Data Book. Red data book also gives information about the urgency of their conservation problems to the public and policy makers.

Examples: Animals-

- (1) Pigmy hog (Sus salvanius)
- (11) Red Panda (Ailurus fulgens)

Plants—(i) Berberts nilghirtensis

(11) Bentinckia nicoberica.

[20] Mention the scientific name of Lac insect. What are the uses of Lac insect product?

Ans. Scientific name: Tachardia lacca.

Uses. Shellac is the product of lac insect. Shellac is used in different manufacturing substances, such as in variations, paints, scaling wax, insulating cable wires etc.

[21] Name some recombinant DNA products.

Ans. Enzymes, vaccines, interferons and human hormones

[22] What are the stages of gene cloning?

Ans. The stages of pene cloning are breaking of cells, isolation of DNA cutting off of the desired genes, incorporation of the desired gene into the vector, multiplication of the recombinant DNA molecule.

[23] Name 2 organisms used as single cell proteins.

Ans. Succharomyces cerevisiae Jungus Methylophilus methylotrophus bacteria.

[24] Name two organisms used in biodegradation.

Ans. Nocardia, Streptomyces.

[25] What is superbug?

Ans. The organism Pseudomonas putula developed by A.M. Chakraborty used in decompositive petroleum is called superbug.

[26] What is Bs cyanobacteria?

Ans. The transcenic evanobacteria containing the Bs. toxin producing gene obtained from *Bacillus sphaericus* is called Bs evanobacteria, which is used in controlling mosquito larvae and thus prevents malaria.

[27] What are RIP tobacco ?

Ans. The transgeme tobacco containing the tibosome mactivating gene which makes it resistant against *Rhizoctonia solum*

[28] What is MTLT rice?

Ans. The draught resistant rice capable of producing mainted is called MTLT rice

[29] Which I athyrus is without any side effect?

Ans. The transpenic Lathyrus containing the ONDC (oxalate decarboxylase) gene is without any toxic side effect.

[30] What is bio-plastic?

Ans. The compound called poly hydroxy alkanoate obtained from bacteria *Chromobacterium* is bio-plastic because it is biologically degraded.

[31] What is monoclonal antibody?

Ans. The type of antibody active against a specific type of antigen is monoclonal antibody. It is obtained with the help of hybridoma technology.

[32] What are interferons?

Ans. A group of low molecular weight (20-30kd) animal proteins, that prevent the growth of specific animal viruses is known as interferon. It can be classified as IFN α , IFN β and IFN γ .

[33] What are stem cells?

Ans. The stem cells are specialized cells isolated from six week old embryos, which have the ability to regenerate into complete organs.

[34] How DNA is amplified?

Ans. DNA amplification takes place with the help of polymerase chain reaction.

[35] Why DNA fingerprinting is important?

Ans. It helps in the proper ideatification of a person, in solving paternal dispute, in detection of a criminal.

[36] How gene mapping is made?

Ans. The gene mapping is done on the basis of the study of the linkage groups, segregation of cell hybrids, use of molecular markers, restriction fragment length polymorphism.

[37] What is M.S. medium?

Ans. The ideal medium for plant tissue culture was denoted by Murashige and Skoog and is known as the M.S. medium.

[38] What are the major steps of plant tissue culture?

Ans. It involves sterilization of glassware, plant material, culture and organogenesis.

[39] What are the major applications of plant tissue culture?

Ans. Plant tissue culture helps in DNA amplification, production of haploids, monoploids, protoplast culture, micro propagation and somaclonal variation.

[40] What are the major applications of animal tissue culture?

Ans. The major applications of animal tissue culture are production of hybridoma, monoclonal antibody and transgenic animals.

[41] What is totipotency?

Ans. The ability of an organism to produce an entire body from a single cell is known as totipotency. Plant cells have this ability, while animal cells do not have this.

[42] What are artificial seeds?

Ans. The embryos initiated in callus culture when covered by calcium alginate produces the artificial seeds.

[43] What is rejuvenating hormone?

Ans. Kinetin is termed as rejuvenating hormone because it delays senescence.

[44] Name the chemical rings of IAA and GA₃.

Aus. The chemical rings of IAA and GA₃ are the Indole ring and Gibbane ring respectively.

What is the result of apical dominance? [45]

Ans. The result of apical dominance is apical growth.

- How GA, breaks dormancy of seeds? [46] Ans. It cause de-novo synthesis of α-amylase, which breaks the stored starch of endosperm into soluble forms, increases the osmotic pressure and brings about germination.
- Name two major cytokinin compounds. [47] Ans. They are kinetin and zeatin.
- What is the function of traumatic acid? [48] Ans. It causes healing of wound in plants.
- Which hormone is used for ripening of fruit? [49] Ans. Ethylene.
- Why tea plants are pruned regularly? [50] Ans. This removes the apical buds, so apical dominance is checked and lateral branches grow to give a bushy appearance.
- What is auxin? What is its role in phototropism? [51] Ans. Auxin is a major growth hormone in plants. Auxin is deposited on the stem surface away from the light, so that the side grows at a faster pace and the shoot bends towards light.
- What is the chemical nature of abscisic acid? [52] Ans. It is a sesquiterpenoid compound with the formula of $C_{15}H_{20}O_4$.
- Who proposed ethylene as a phytohormone? [53] Ans. Neljobow (1901) first reported the role of ethylene in plant growth. Pratt and Goexhl (1969) proved the role of ethylene as a phytohormone.
- What are the two types of brain waves? [54] [J.E.E. 2000] Ans. Alpha waves, Beta waves, Theta waves, Delta waves. (Mention any two)
- What do you mean by cryopreservation of sperms, ova and embryos? [55] Ans. The process of preserving sperms, ova and embryos in frozen state at a very low temperature is referred to as cryopreservation of these materials, By this, the sperms, ova or embryos can be stored for a long time without loss of their potentiality.
- Is the term 'test tube baby' justified? Give reason. [56] Ans. No, the term 'test tube baby' is not justified because in such cases, neither the fertilization takes place in a test tube nor the baby is reared in a test tube.
- How a couple may have a child if (a) the husband cannot produce sperms, [57] and (b) the fallopian tubes of the wife are blocked?
 - Ans. (a) If the husband cannot produce sperms, the couple may have a child either by artificial insemination or by in-vitro fertilization and embryo transfer (IVF-ET) technique, using donor's sperm so that the wife may conceive and give birth to a child.
 - (b) If the fallopian tubes of the wife are blocked, the couple may have a child by adopting the technique of IVF-ET using the wife's ova and husband's sperms.
- Name two imaging techniques commonly used to detect brain tumors. [58] Ans. Computed tomographic scan (CT scan) and magnetic resonance imaging (MRI).

[59] Name the technique which helps in detection as well as surgical treatment of some internal organ disorders.

Ans. Endoscopy.

[60] Why a blood dializer (hemodializer) is called artificial kidney?

Ans. A blood dializer is called artificial kidney because it helps to purify blood by removing urea and other excretory matters from the blood.

[61] (a) Name two clinical devices commonly used to detect the position of foetus?

(b) Which one is safer and why?

Ans. (a) X-ray radiography and ultrasonography (USG).

(b) USG is safer than X-ray radiography because the X-ray may produce the ill effects of ionizing radiation, while the USG does not have ionizing effects.

EXERCISE

• A.	Essay type /Long Answer type :	
[1]	What is biofertilizer? Describe how bacteria acts as biofertilizer	(Ans. 14.1)
1	What is mycorrhizae? Describe the different types.	(Ans. 14.1)
[2]		. 14.2.1 & 14. 2.3)
[4]	How man is affected by pesticide ? Write what you know about the hazards of pestic	
[4]	flow main is affected by pesticide with mine you allow door the manner of the	(Ans. 14.2.5)
[5]	Describe the different types of agents of biological control.	(Ans. 14.2.7)
[6]	Write what you know about disadvantages of biological control	(Ans. 14.2.8)
[7]	Describe the origin of domesticated animals and cultivated plants	(Ans. 14.3.2)
[8]	Define endangered species Describe the causes of rapid decline of wild species.	
11	(An	s. 14.4.1 & 14.4.2)
[9]	Write what you know about the importance of conservation of threatened species.	(Ans. 14.4.3)
[10]	Write in short about the methods of conservation of endangered species.	(Ans. 14.4.4)
juj	What is sericulture? Write in short about the rearing process of mulberry silk-worm	l.
` '		(Ans. 14.5.1)
[12]	What is apiculture? Describe the scientific method of beekeeping.	(Ans. 14.5.2)
[13]	What is lac culture? Describe the scientific method of lac cultivation.	(Ans. 14.5.3)
[14]	Describe the life history of lac insect. Mention the composition of uses of lac.	(Ans. 14.5.3)
[15]	Tribut to discontinuous by . diene the thinger at the	(Ans. 14.6, 14.6.1)
[16]	State and describe the outline of gene cloning procedure	(Ans. 14.6.2)
[17]	What are transgenies? Describe some useful transgenic microbes.	(Ans. 14.6.2)
[18]	How transgenic plants are useful ?	(Ans. 14.6.2)
[19]	Describe the usefulness of transgenic animals.	(Ans. 14.6.2)
[20]	What is sperm and ova bank? What are its objectives?	(Ans. 14.6.3)
[21]	What is test-tube baby? How is it produced?	(Ans. 14.6.3)
[22]	What do you mean by surrogate mother? Why and how is it used?	(Ans. 14.6.3)
[23]	What is DNA fingerprinting? State its uses.	(Ans. 14.6.4)
[24]	What are the techniques involved in gene mapping, Describe them.	(Ans. 14.6.5) (Ans. 14.6.7)
[25]	What are the applications of plant tissue culture? State the method employed in plant tissue culture.	(Ans. 14.6.7)
[26]	Describe the various applications of animal tissue culture.	(Ans. 14.1)
[27]	How is hormone used in the improvement of agriculture?	(Ans. 14.6.8)
[29]	What is the full name of IAA? State its functions.	(Ans. 14.6.8)
[30]	What are electrocardiograph and electroencephalograph? Write their uses.	(Ans. 14.6.10)
[31]	Write the principle, advantages and disadvantages of auto-analyzer	(Ans. 14.6.10)
[32]	Write the principle and clinical uses of USG and CT scan	(Ans. 14.6.10)
[33]	What is X-ray imaging? Write its uses.	(Ans. 14.6.10)
[34]	What are fluoroscopy and endoscopy Write their principle and clinical uses.	(Ans. 14.6.10)
[35]	What is MRI? Write its principle and uses.	(Ans. 14.6.10)
[36]	What do you mean by laser therapy? Mention its uses.	(Ans. 14.6.10)
[37]	What is blood dialyzer? Discuss its principle and use.	(Ans. 14.6.10)
[38]	Write briefly about artificial pacemaker and heart lung machine.	(

• 1	3. Short Answer type:	
[1		(Ans. 14.1)
[2		(Ans. 14.1)
[3		(Ans. 14.1)
[4		(Ans. 14.1)
[5		(Ans. 14.1)
[6		(Ans. 14.1)
17		(Ans. 14.2.1)
[8]		(Ans. 14.2.3)
[9		(Ans. 14.2.4)
[10		(Ans. 14.2.5)
[11		(Ans. 14.2.6)
[12		(Ans. 14.2.7)
[13	The state of the s	(Ans. 14.2.8)
[14	What are cultigens and inquilines?	(Ans. 14.3 & 14.3.1)
[15		(Ans. 14.4.2)
16		(Ans. 14.4.4)
[17		(Ans. 14.4.4)
[18		(Ans. 14.4.6 & 14.4.5)
[19		(Ans. 14.5.1)
[20]	,	(Ans. 14.5.3)
[21]		(Ans. 14.6)
[22]		(Ans. 14.6.2)
[23]		(Ans. 14.6.2)
[24]		(Ans. 14.6.2)
[25]	7	(Ans. 14.6.2)
[26]		(Ans. 14.6.2)
[27]		(Ans. 14.6.2)
[28]		(Ans. 14.6.2)
[30]		(Ans. 14.6.2)
[31]		(Ans. 14.6.2)
[32]		(Ans. 14.6.2)
[33]	2 Francisco III a specific administra	(Ans. 14.6.3)
[34]		(Ans. 14.6.3)
[35]		(Ans. 14.6.3)
[36]		(Ans. 14.6.3)
[37]	How is a DNA fingerprint produced?	(Ans. 14.6.3)
[38]	What is meant by restriction fragment length polymorphism?	(Ans. 14.6.4)
[39]	What is MS Medium?	(Ans. 14.6.5)
[40]	What are haploids and monoploids ?	(Ans. 14.6.7)
[41]	What is micro propagation?	(Ans. 14.6.7)
[42]	What is Richmond & Lang's effect ?	(Ans. 14.6.7)
[43]	How is senescence controlled by phytohormone?	(Ans. 14.6.10)
[44]	What do you mean by electrocardiogram and electrocardiograph?	(Ans. 14.6.10)
[45]	Show diagrammatically the waves of ECG.	(Ans. 14.6.10)
[46]	Name the EEG waves.	(Ans. 14.6.10)
[47]	What is an autoanalyzer ?	(Ans. 14.6.10)
[48]	Name six imaging devices used clinically.	(Ans. 14.6.10)
[49]	Why blood dializer is called 'artifical kidney'?	(Ans. 14.6.10) (Ans. 14.10, Q-60)
[50]	What are natural and cardiac pace-makers ?	
[51]	What is heart lung machine?	(Ans. 14.6.10)
[52]	What do you mean by proctoscopy and cystoscopy ?	(Ans. 14.6.10)
		(Ans. 14.6.10)
	Specific Answer type :	
[1]	What is cyanobacteria?	(Ans. 14.1)
[2]	What is leg haemoglobin?	(Ans. 14.1)
[3]	Which cyanobacteria is used widely in sugarcane field?	(Ans. 14.1)
[4]	Why is Azolla important in paddy field?	(Ans. 14.1)
[5]	Why the group of insecticide is known as contact poison?	(Ans. 14.2.4)

050		
[6]	Which agent is used widely in biological pest control 9	(Ans. 14.2.7)
171	Why the South-east Asian countries are regarded as the centre of first domesticat	ion of aminals and
(-)	nlants 7	fr monder n nominal
[8]	How the International trade causes rapid decline of wild species?	(Ans. 14.4.2)
[9]	Which endangered wild animal is protected in Jaldapara sanctuary	(Ans. 14.4.4)
[10]	Why the nets are used in rearing silk-worm?	(Ans. 14.5.1)
[11]	Who prepared the first gene assemblar?	(Ans. 14.6)
[12]	What is gene cloning?	(Ans. 14.6.2)
[13]	Name two transgenic vaccines.	(Ans. 14.6.2)
[14]	What is hydrogen fuel?	(Ans. 14.6.2)
[15]	Name two phytoalexins.	(Ans. 14.6.2)
[16]	What is MTLT gene ?	(Ans. 14.6.2)
[17]	What is the role of IPT gene?	(Ans. 14.6.2)
[18]	What is AmA potato?	(Ans. 14.6.2)
119	What are the different types of T cells?	(Ans. 14.6.2)
[20]	State the different types of interferon.	(Ans. 14.6.2)
[21]	Who discovered the test tube haby 9	(Ans. 14.6.3)
[22]	Name the first test tube baby of the world and mention where and when she was be-	rn (Ans. 14.6.3)
[23]	At what temperature the speem and ova are preserved in sperm and ova bank	(CIN, 1960a)
[24]	Name the first test tube baby born in India? Where and when she was born?	exas, 14.6.3)
[25]	Give the full name of IVF-ET.	(Ans. 14.6.3)
[26]	What is gene therapy?	(Ans. 14.6.2)
[27]	What is Southern Blotting?	(Ans. 14.6.4)
[28]	What are molecular markers?	(Ans. 14.6.5)
[29]	What is cybrid?	(Ans. 14.6.7)
[30]	What is tolipotency?	(Ans. 14.6.6)
[31]	What are roles of 2,4-D and 2,4,5-T?	(Ans. 14.6.8)
[32]	What are the two types of brain waves? [J.E.F. 2000]	(Ans. 14.10, Q-54)
[33]	Name the scientists who discovered the following:	
,	(a) ECG, (b) CT Scan, (c) X-ray, (d) Endoscopy.	(Ans. 14.6.10)
[34]	Give the full names of the following:	
1- 7	(a) EEG, (b) I CG, (c) MRI, (d) USG, (e) PFT scan, (f) CT scan	(Ans. 14.6.10)
[35]	Who is known as father of electrocardiography?	(Ans. 14.6.10)
[36]	Name two clinical devices used to detect the position of foetus?	(Ans. 14.10, Q-61)
• D	Distinguish between:	
[11]	Fertilizer and Manure.	(Ans. 14.1)
[2]	Ectorycorrhiza and Endomycorrhiza.	(Ans. 14.1)
[3]	Fungicides and Insecticides.	(Ans. 14.2.1)
[4]	Stomach poison and Contact poison.	(Ans. 14.2.4)
[5]	Parasites and Parasitoids.	(Ans. 14.2.7)
[6]	Cultigens and Inquilines.	(Ans. 14.3.1)
[7]	National Park and Sanctuary.	(Ans. 14.4.4)
[8]	Auxin and Gibberellin.	(Ans. 14.6.9)
[9]	Auxin and Cytokinin.	- (Ans. 14.6.9)
[10]	Gibberellin and Cytokinin.	(Ans. 14.6.9)
[11]	Biofuel and Bioplastic.	(Ans. 14.6.2)
[12]	Callus and Haploid culture.	(Ans. 14.6.7)
• E.	Write short notes on:	
	141 C 1	(anc. 14.7.4) [4]

[1] Cyanohacteria (Ans. 14.1) [2] Mycorrhizae (Ans. 14.1) [3] Contact poisons (Ans. 14.2.4) [4] Funugants (Ans. 14.2.4) [5] Red Data Book (Ans. 14.4.5) [6] Recled silk (Ans. 14.5.1) [7] Brood Chamber (Ans. 14.5.2) 8. Female Lac cell. (Ans. 14.5.3) [9] Gene cloning (Ans. 14.6.2) [10] Chimeric DNA (Ans. 14.6.2) [11] Biodegradation (Ans. 14.6.2) [12] Fungal resistant transgenic plant (Ans. 14.6.2) [13] Stress resistant transgenic plant (Ans. 14.6.2) [14] Biofuel (Ans. 14.6.2) [15] Interferon (Ans. 14.8.3) [16] Gene replacement therapy (Ans. 14.8.3) [17] Stem cell (Ans. 14.8.3) [18] DNA ingerprinting (Ans. 14.6.4) [19] R F I P (Ans. 14.6.5) [20] Protoplast fusion (Ans. 14.6.7) [21] Micropropagation (Ans. 14.6.7) [22] Monoalonal antibody (Ans. 14.6.2) [23] Abscission (Ans. 14.6.8) [24] Control of flowering (Ans. 14.6.8) [25] Sperm bank (Ans. 14.6.3) [26] Ova bank (Ans. 14.6.3) [27] Fest-tube baby. (Ans. 14.6.3) [28] Surrogate mother (Ans. 14.6.3) [29] LCG (Ans. 14.6.10) [30] USG (Ans. 14.6.10) [31] CT scan (Ans. 14.6.10) [32] MRI (Ans. 14.6.10) [33] Endoscopy (Ans. 14.6.10) [34] Pacemaker (Ans. 14.6.10) [35] Laser therapy (Ans. 14.6.10)

. F. Put ✓ Mark on Correct Answer:

- III Biofertilizer include cyanobacteria/bacteria/mycorrhizae/all.
- [2] Associated mutualism is exhibited by Azospirillum/Rhizobium/Azotobacter.
- [3] The pigment present in root nodule of legame plant is haemoglobin/leg haemoglobin/lycopin
- [4] Azolla contains colony of Anabaena/Nostoc/Cylindrospermum.
- [5] Insecticide when it is used for killing termites is known as (termicide/fungicide/herbicide)
- [6] Free living organisms that feed on other animals are known as (Parasites/Predators/Parasitoids)
- [7] Freshly hatched larvae of mulberry silk moth are transferred to the (Mountage/Rearing stand/Rearing tray).
- [8] Main product of honey bee is (Lac/Honey/silk).
- [9] The distance between the two trames of broad chamber is known as thee space Comb foundation/excluder)
- [10] Each larva of lac insect gets fully covered by the resinous substance to form a (lac-cell/swarming/incubating chamber).
- [11] Genetic knife is the other name for restriction endonuclease exonuclease/polymerase
- [12] Example for single cell protein is yeast/Candida/ Trichoderma/all.
- [13] Biodegradation is carried out by Noccardia/Streptomyces/both.
- [14] AmA gene is isolated from bacteria/higher plant/fungi.
- [15] Stem cells are isolated from human/lower animal/plants/microbes.
- [16] Polymerase chain reaction was denoted by Jeffrey/Mullis/Lalji Singh.
- [17] The computer software used in gene mapping gene map/map maker/genetica
- [18] Artificial seeds are obtained with the help of sodium alginate/calcium alginate/potassium alginate.
- [19] Micropropagation was initiated by Skoog/Murashige/Steward.
- [20] Effectively weed control is brought about by IAA/NAA/2, 4-D.
- [21] Usually liquid oxygen/carbon dioxide/nitrogen is used in sperm banks.
- [22] In 'test tube baby' technique the ovum is fertilized in fallopain tube/test tube/petridish
- [23] Donor's sperm stored in sperm bank may be used for IVF surrogate motherhood.
- [24] World's first test tube baby was born in U.K./U.S.A/India.
- [25] India's first test tube baby was born in Delhi/Chennai/Mumbai.
- [26] ECG is the recording of heart's electrical activity / contraction and relaxations
- [27] EEG is recorded from the surface of brain/scalp.
- [28] Gall stone can be detected by laser/USG/EEG.
- [29] Laser beam is used for diagnostic imaging/surgery.
- [30] Renal stone can be detected by dializer/USG.

A surrogate mother lends her -

[23]

[24]

[25] [26]

G. Fill in the blanks

	3.	rn in the drains :
[1	1	Biofertilizer includes——, —— and———.
[2		andare two free-living nitrogen fixing bacteria.
13]	exhibits double symbiosis.
14	1	Azolla plant body contains——.
15	1	Insecticides that enter the insect body through the gut of the pest is known
[6	J	Cultivated plants and domesticated animals are together known as
[7	1	South-west Asian countries appear to be the home of ——and grazing——.
[8	9	The wildlife is maintaining the ecosystem of nature through the balance of and food
[9	1	Aim of the crocodile project is to collect their ——, after hatching rear them in the tank.
[10	1	Larvae of Bombyx mori feed only onof mulberry
[11]	The transfer of gene is brought about by———, commonly called ———
[12	1	The vector with the desired gene is called———
113	1	The delay in senescence is brought about bygene.
[14	1	The detoxification of Lathyrus is brought about by——gene.
(15		The bacteria producing bio-plastic is
[16	1	Broadly there are—types of interferon.
[17	1	Stem cell is obtained from——embryo of man.
[18	1	Cell fusion is halped by——virus.
[19	1	Endonuclease is also called-
120	1	The ideal medium for tissue culture is———medium.
[21	J	Sperms and ova are stored by .
[22	1	For test tube baby, fertilization occurs the uterus.

In IVF-ET four to ---- cell stage embryo is transferred into the uterus.

---- therapy is used for surgical removal of cataract and renal stone.

- is used to make the free from nitrogenous waste matters.

- [28] Heart lung machine is required for —— surgery.

● H. Put√Mark on Yes/No for the right Answer:

- [1] Manures are also called biofertilizer—Yes/No.
- [2] Mutualism differs from associative symbiosis—Yes/No.
- [3] Leg haemoglobin is also found in non-legume plant—Yes/No.
- [4] Azolla cannot fix atmospheric nitrogen by itself-Yes/No.
- [5] Pesticides create hazards to human health.—Yes/No.
- [6] Insects pests are also affected by pathogenic micro organisms Yes/No.
- [7] The importance of wild species lies in the breeding programmes in animal husbandry and agriculture— Yes/No.
- [8] Mulberry silk-worm is producing shellac-Yes/No.
- [9] Mountage is required for rearing of larvae of silkworm.—Yes./No.
- [10] Apis dorsata is domesticated for apiculture.—Yes/No.
- [11] Chimeric DNA is the other name for the vector —Yes/No.
- [12] Both bacteria and fungi belong to single cell protein —Yes/No.
- [13] Bio-mining is carried out by bacteria—Yes/No.
- [14] B.s. toxin is a fungal toxin-Yes/No.
- [15] Zeamatin is a phytoalexin of maize—Yes/No.
- [16] Pisatin is a phytoalexin of pea.—Yes/No.
- [17] Bio-plastic is actually poly hydroxy alkanoate polymer—Yes/No.
- [18] Stem cells are obtained from microbes—Yes/No.
- [19] Interferons are specific in nature—Yes/No.
- [20] Bio-markars are ideal for gene mapping—Yes/No.
- [21] Sperm and ova banks are beneficial for fertile couple—Yes/No.
- [22] A lady is artificially inseminated for having a test tube baby.—Yes/No.
- 1231 A test tube baby is reared in a test tube.—Yes/No.
- [24] EEG helps to detect injury of spinal cord.—Yes/No.
- [25] T-wave of ECG represents atrial depolarisation.—Yes/No.
- [26] USG is safer than X-ray radiography.—Yes/No.
- [27] CT scan and endoscopy are done to detect tumors or injuries in brain. -Yes/No.
- [28] Fluoroscopy is a type of endoscopy.—Yes/No.

Answers to Q. No F, G & H.

- [F] [1] all [2] Azospirllum [3] leg haemoglobin. [4] Anabaena. [5] termicide [6] Predators [7] Rearing tray. [8] Honey [9] bee space [10] lac cell. [11] restriction endonuclease [12] all [13] both [14] higher plant [15] human [16] Mullis. [17] map maker [18] calcium alginate [19] Steward [20] 2, 4-D [21] nitrogen [22] petridish [23] IVF [24] U.K. [25] Mumbai [26] electrical actrivity [27] scalp [28] USG [29] surgery [30] USG.
- [G] [1] bacteria, cyanobacteria, mycorrhizae [2] Azotobacter. Clostridium. [3] Sesbania rostrata [4] Anabaena colony [5] Stomach poison [6] cultigens [7] Wheat, mammals [8] population, chains [9] eggs, nursery [10] leaves, plant. [11] plasmid, vector [12] chimeric DNA. [13] IPT (iso pentanyl transferase) [14] OXIOC. [15] Chromobacterium [16] three. [17] human. [18] sendai [19] genetic knife. [20] M.S. (Murashige Skoog).
- [H] [1] No [2] Yes [3] No [4] Yes [5] Yes [6] Yes [7] Yes [8] No [9] No [10] No [11] No [12] Yes [13] Yes [14] No [15] No [16] Yes [17] Yes [18] No [19] Yes [20] Yes [21] No [22] No [23] No [24] No [25] No [26] Yes [27] No [28] No

APPENDIX

Some typical and critical questions which are very often set in different competitive examinations like Joint Entrance Examination and other All India Competitive Examinations have been appended here along with suggestive answers. This part will help the JEE aspirants in a great way. Students are advised to go through this section only after the text portion of this book is read throughly.

Chapter 1: Nature and Scope of Biological Sciences

• [A] Long answer type questions:

1. Give an account of Susruta's contribution in the field of biology and surgery. Ans. In ancient India, during the period of 600 B.C. Susruta classified the living organisms into two main groups, such as Sthavara (immobile) and Jangama (mobile), This is mentioned in his book 'Susruta Samhita'. In this book, he mentioned the plants as immobile organisms. He classified the plants into 4 groups, such as Vanaspati, Vraksa, Virudha and Osadhi. Fruit yielding non-flowering plants are known as Vanaspati; Vraksa means fruit-yielding flowering plants; shrubs and creepers are regarded as Virudha and plants that die with ripening of fruits are known as Osadhi. He even described in detail the different parts of a plant. Susruta mentioned the following structures of a plant, such as ankura (sprout), mula (root), kanda (stem), patra (leaf), puspa (flower), phala (fruit) Susruta also tried to classify the animal kingdom. He treated the animals as mobile organisms, so he named them as Jangama. Susruta classified the animals into the following groups, such as Kulacara, Matsya, Janghala and Guhasaya. The animals which are herbivorous and frequently visiting the river banks are regarded as Kulacara, such as buffalo, elephant etc. Fishes are included in a group called Matsya. Four footed wild herbivorous animals are included in a group entitled Janghala, as for example deer. Four footed wild carnivorous animals are included in a group is known as Guhasaya. Susruta's observation on poisonous and non-poisonous snakes as well as leeches are depicted in his book 'Susruta Samhita.'

Susruta studied human anatomy on dead body. Susruta contributed significantly in surgery. He himself carried out plastic surgery on human body. He developed the process of anesthesia and sterilization before undertaking the surgery proper. He also performed the treatment of human cataracts in eye. During operations, he introduced the non-poisonous living leeches for preventing the blood clotting. Now it is known that leeches secrete an anticoagulant substance known as *heparin* along with saliva. Leeches secrete heparin to prevent blood clotting during sucking of blood from the host. For his great contribution in the field of surgery, Susruta is regarded as the 'father of surgery'.

2. Write what you know about the contributions of Charaka in the field of biology and medical science.

Ans. Charaka was an eminent Indian medical practitioner of ancient period. He also wrote a book known as 'Charaka Samhita' near about 100 B. C. In this book, he metioned the classification of animals based on their food habits and habitats. But this classification was not fully scientific from the modern point of view. He also mentioned near about 400 medicinal plants in this book.

Charaka made for the first time the concept of digestion of food material, metabolism and immunity. Charaka mentioned that normal functioning of the body is due to proper balance of the three doshas — bile (pitta), phlegm (kaph) and wind (vayu). When the balance among the three doshas in a human body is disturbed, illness is caused. He prescribed medicines for treating the illness and restoring the balance among the doshas, so that the human body may become normal. Charaka also had fundamental knowledge of geneties. He described the factors that determined the sex of a child. Ayurveda, the Indian system of medicine was developed by taking ideas largely from the doctrines of Charaka Samhita.

Charaka thought that the individual is a replica of the universal spirit. He thought that man and the visible world both are composed of six elements. These elements are *prithvi*, ap, tejas, vayu and akasa i.e. earth, water, fire, air and ether. The sixth element is the spirit or self in the individual which is equivalent to Brahman in the Universe.

• [B] Short answer type questions:

1. What do you mean by the term science?

Ans. The term Science is derived from the Latin word Scientia which means knowledge. Previously it was used for the knowledge of any kind. But at present it means the organised knowledge based on observation and experimentation. Hence, science may be defined as the study of knowledge in a logical and orderly fashion obtained by observation, experimentation, interpretation and testing.

2. Why do the biologists need to study Chemistry and Physics?

Ans. The knowledge of other basic sciences particularly chemistry and physics is necessary to study biology. Now a days biochemistry and biophysics have developed as new branches of science. These two new branches deal with the application of chemistry and physics to explain the biological phenomena. All life forms obey and are completely explained by the law of chemistry and physics. We understand life by understanding the chemistry of organic molecules and ions, and we understand chemistry by knowing the properties of atoms and how they are influenced by energy, gravity, and other physical phenomena. Hence a sound knowledge of basic sciences, such as chemistry and physics is useful in understanding life processes.

3. What is the function of controlled experiment in the scientific method?

Ans. A control experiment is set up along with the actual experiment. In the control experiment one of the factor is eliminated which is to be tested. Normally, a scientist performs two sets of parallel experiments that are identical in all respects except in one factor. Control experiment establishes the validity of the actual experiment and helps the investigator to know the effect of this experimentation.

4. Why biology is called a science of exceptions?

Ans. In biology, there are many exceptions. This is due to the fact that biology deals with living organisms which show wide variations. Living organisms are adapted to variable environments with variable modes of life as well as feeding habits, thus showing various degrees and directions of changes in their body parts.

5. Mention some of the common examples of exceptions in biology.

Ans. Some common exceptions are given below:

- (a) Mammals give brith to young ones, but some primitive mammals lay eggs, such as duck billed platypus and spiny ant eater (Echidna).
- (b) The heart of reptiles is three chambered but in crocodile (reptile), the heart is four chambered.

(c) In plants, the recets are devoid of chlorophyll and are non-green in colour. But the assimilatory root of finospora contain chlorophyll and they are green and photosynthetic in nature

(d) Leaves of monocot plants show parallel venation. However, the leaves of some

monocots have reticulate venation, such as Colocasia.

• [C] Multiple choice type questions:

1. Who is Known as 'father of Zoology'?

- (a) Darwin
- (b) Lamarck
- (c) Linnaeus
- (d) Aristotle

2. Branch of biology dealing with study of extinct plants is-

- (a) Palynology
- (b) Palaeobotany
- (c) Anthropology
- (d) Anatomy

3. Branch of biology dealing with study of cell is--

- (a) Histology
- (b) Morphology
- (c) Cytology
- (d) Ecology

4. Which of the following cells in plant show totipotencey?

- (a) Meristem
- (b) Xylem Vessel
- (c) Cork cells
- (d) Sieve tubes.

5. Study of fossils is called-

- (a) Genetics
- (b) Cytology
- (c) Palaeontology
- (d) Evolution.

6. The branch of biology connected with the improvement of human race through laws of heredity is—

- (a) Ethnology
- (b) Erethemics
- (c) Genetics
- (d Eugenics.

7. Who is Known as the 'father of surgery'?

- (a) Charaka
- (b) Susruta
- (c) Dhanwantari
- (d) Atreya.

8. Who is known as the 'father of anatomy'?

- (a) William Harvey
- (b) Andreas Vesalius
- (c) Robert Hooke
- (d) Anton Van Leeuwenhoek.

9. Technique of sterilization was first introduced by-

- (a) Ivan Petrovich Pavlov
- (b) Alexander Fleming
- (c) Louis Pasteur
- (d) Carolus Linnaeus.

10. Who is regarded in India as the 'God of medicine'?

- (a) Ashwinikumar
- (b) Charaka
- (c) Dhanwantari
- (d) Susruta.

11. The branch of biology that deals with bird is known as

- (a) Entomology
- (b) Ichthyology
- (c) Agronomy
- (d) Ornithology.

12. Which of the following promotes similarity among living things?

- (a) Natural selection in different environments
- (b) Inheritance from a common ancestor
- (c) Homeostatic regulation
- (d) Classification of organisms.

Answers to Q. C

- 1. Aristotle.
- 2. Palaeobotany. 4 3. Cytology

- 4. Meristem.
- 5. Palaeontology.
- 6. Eugenics.
- 7. Susruta 10. Dhanwantari. 11. Omithology.
- 8. Andreas Vesalius. 9. Louis Pasteur
 - 12. Inheritance from a common ancestor.

Chapter 2: Unit of Life

• [A] Distinguish between:

1. Distinguish between simple microscope and compound microscope.

Ans.

-		
Simple microscope	Compound microscope	
(i) It contains draw tube but not the	(i) It contains both draw tube and	
body tube.	body tube.	
(ii) It does not contain nose piece.	(ii) It contains a nose piece.	
(iii) It has only one pair of focussing	(iii) It has two pairs of focussing	
(adjustment) screws	(adjustment) screws coarse and fine.	
(iv) It does not have substage	(iv) It has substage condenser and	
condenser and diaphragm.	diaphragm.	
(v) It contains only one set of	(v) It contains two sets of maginifying	
magnifying lens the eyepiece	lenses—the eyepiece and the objective.	
(vi) It has a low magnifying power,	(vi) Its magnifying power is much	
usually upto 20 times	higher, usually upto 1500 times.	

2. Differentiate between compound microscope and electron microscope. Ans.

Compound microscope	Electron microscope
(i) Beam of light is used for image	(i) Beam of electrons is used for
formation.	image formation.
(ii) Contains glass lenses for	(ii) Contains electromagnetic lenses
magnifying the image.	for magnifying the image
(iii) The specimen examined may be	(in) The specinen examined is usually
living or non-living and supported on a	non-living and supported on a grid made
glass slide.	of noble metal.
(iv) The stains used are coloured dyes.	(iv) The stains used are heavy metals.
(v) The image formed is usually	(v) A black and white image is
coloured.	formed.
(vi) The image is viewed directly	(vi) The image is viewed on a
through the eyepiece.	flourescent screen.
(vii) The magnifying power is usually	(vii) The magnifying power is upto
up to 1500 times.	250000 times.
(viii) Resolving power is 200nm.	(viii) Resolving power is 0.5 nm.

3. Distinguish between transmission electron microscope (TEM) and scanning electron microscope (SEM).

Ans.

Transmission electron microscope	Scanning electron microscope	
(i) Image is produced by passage (transmission) of electrons through the	(i) Image is produced by electrons reflected from the surface of specimen.	
specimen. (ii) It gives a cross sectional view of the object. (iii) Very thin sections or small particles are used as specimen. (iv) Resolving power is much higher (0.5 nm).	(ii) It gives a three dimensional view of the surface structures. (iii) Only larger specimens can be observed. (iv) Resolving power is lower (5-20 nm).	

4. Distinguish between primary cell wall and secondary cell wall. Ans.

Primary cell wall	Secondary cell wall
(i) Located just inside the middle lamella. (ii) Found in all plant cells.	(i) Located inside the primary cell wall. (ii) Usually found in dead cells and
(iii) Formed when the cell is growing	vascular tissue cells of plants. Absent in meristematic tissues and cambium. (111) Formed when growth of the cell has ceased.

5. Distinguish between chloroplast and amyloplast.

Ans.

Chloroplast	Amyloplast
(i) It is the green coloured plastid. (ii) It contains chlorophyll for	(i) It is a colourless plastid. (ii) It contains starch as stored food.
synthesis of starch.	
(iii) It has grana.	(iii) It does not have grana.
(iv) It is found in those parts of a plant	(iv) It is found in underground parts
that are exposed to sunlight e.g. leaves	of a plant that are not exposed to sunlight
and stems.	e.g. roots and underground stems.

6. Distinguish between chromoplasts and amyloplasts

Ans.

Chromoplasts	Amyloplasts
(i) These are coloured but non-green	(i) These are colourless plastids.
plastids.	
(ii) They contain pigments other than	(ii) They contain starch grains.
chrolophyll e.g. carotenoids and	
xanthophyll.	
(iii) They help in colouration of plant	(iii) They help in storage of food
parts for pollination and dispersal of	(starch).
seeds.	

7. Distinguish between cystoliths and raphides.

Ans.

Cystoliths	Raphides
(i) These are crystals of calcium	(i) These are crystals of calcium
carbonate stored in plant cells as an	oxalate stored in plant cells as an ergastic
ergastic excretory substance.	excretory substance.
(ii) They look like bunch of grapes.	(ii) They are star-shaped and look like
	bunch of fine needles.
(iii) They remain within specialised	(iii) They remain with specialised
cells called lithocysts.	cells called idioblasts.
(iv) They are seen in leaves of banyan,	(iv) They are seen in leaves of water
fig, rubber etc.	hyacinth, taro, arum etc.

8. Distinguish between microvilli and cilia.

Ans.

Microvilli	Cilia
(i) These are minute finger-like	(i) These are hair-like cytoplasmic
projections from the cell surface formed	organelles projecting from the cell
by folding of the cell membrane.	surface.
(ii) They do not contain microtubules.	(ii) They contain microtubules.
(iii) They increase the surface area of	(iii) They are concerned with cell
a cell and help in exchange of materials	motility.
between the cell and its environment.	

- [B] Short answer type questions:
- 1. Who discovered the following?
- (a) cell wall, (b) nucleus. (c) Golgi body, (d) ribosome, (e) nucleolus,

(f) technique of cell fractionation by ultracentrifugation.

Ans. (a) Robert Hooke. (b) Robert Brown. (c) Camillo Golgi. (d) A. Claude.

(e) Wagner. (f) T. Svedberg.

2. Who first proposed the following?

(a) cell theory, (b) trilamellar (protein-lipid-protein) structure of cell membrane,

(c) fluid mosaic model of cell membrane.

Ans. (a) M. J. Schleiden and T. Schwann. (b) Danielli and Davson. (c) Singer and Nicholson.

3. Who gave the name of the following?

(a) unit membrane, (b) plasmalemma, (c) ribosome, (d) mitochondria, (e) protoplasm, (f) cell.

Ans. (a) Robertson. (b) Plowe. (c) G. E. Palade. (d) C. Benda. (e) Purkinje. (f) Robert Hooke.

4. (a) What are microvilli? (b) Mention their function. (c) Give two examples of the cells having microvilli.

Ans. (a) Microvilli are minute finger-like projections present on the surface of certain animal cells, formed by folding of the cell membrane.

(b) Presence of microvilli increases the surface area of a cell to facilitate exchange of material: (absorption or secretion) across the cell membrane.

(c) Mucosal (epithelial) cells of small intestine and the epithelial cells of renal tubules.

5. Give one example of each: (a) unicellular organism having cilia, (b) unicellular organism having flagella, (c) ciliated cell of vertebrate animal and (d) flagellated cell of vertebrate animal.

Ans. (a) Paramoecum or Vorticella. (b) Euglena or Trychonympha. (c) Epithelial cells lining the trachea or oviduct. (d) Spermatozoa.

6. What are permeases or transporters of cell membrane? Mention their functional types.

Ans. Permeases (or transporters) of cell membrane are carrier proteins that help in transport of molecules or ions across the cell membrane. They are of three functional types—uniport, symport and antiport.

7. Name the different types of cell-junctions found in animal cells and mention one example of the cells in which each of these are found.

Ans.

Type of cell Junction

(i) Tight junction (or Zonula occludens)

(ii) Belt desmosome (or Zonula adherens)

(iii) Spot desmosome (or Macula adherens)

(iv) Gap junction (or Nexus)

(v) Interdigitated junction (or Intercalated discs) An example of the cells in which it is found

Brush bordered epithelial cells of small intestine (or renal tubules).

Columnar epithelial cells.

Epithelial cells of epidermis of skin.

Cardiac (or smooth) muscle cells.

Cardiac muscle cells.

8. Name the type of cell junctions in which following structures are found

(a) sealing strands, (b) adherens web, (c) tonofilaments, (d) connexon.

Ans. (a) Tight junctions. (b) Belt desmosomes. (c) spot desmosomes. (d) Gap junctions.

9. What is glycocalyx?

Ans. Glycocalyx is an external covering present around the plasmalemma of some animal cells, which is made up of glycoproteins (or mucopolysaccharides) secreted by the cytoplasm.

10. Name the layers of cell wall from inside outwards.

Ans. (i) Secondary cell wall, (ii) Primary cell wall and (iii) Middle lamella.

11. Which layer of cell wall is common for the adjacent plant cells?

Ans. Middle lamella.

12. Which layer of cell wall of plant cells is formed first?

Ans. Middle lamella.

13. Name the layers of cell wall according to the sequence of their formation.

Ans. (i) Middle lamella, (ii) Primary cell wall, (iii) Secondary cell wall.

14. Name the different types of thickening (or ornamentation) of cell wall.

Ans. (i) Annular, (ii) Spiral, (iii) Scalariform, (iv) Reticulate and (v) Pitted.

15. What is cytosol? Why is it so named?

Ans. The cytoplasmic matrix *i.e.* the fluid ground substance of cytoplasm in which the cytoplasmic organelles and inclusions remain suspended is known as cytosol. It is so named because it is separated as the soluble fraction of cytoplasm or the remaining supernatant after precipitation of all the organelles by centrfugation, during cell fractionation.

16. Name a cell in which mitochondria are: (a) present in large numbers, (b) very few in number and (c) totally absent.

Ans. (a) Cardiac muscle cils, liver cells, cells of proximal tubule of nephron (any one).

(b) Skeletal muscle cells, squamous or stratified epithelial cells (any one).

(c) mature red blood cells of mammals, prokaryotic cells like bacteria (any one).

17. Name a cell in which plastid, mitochondria, endoplasmic reticulum and nucleus are absent.

Ans. Mature red blood cells of mammals.

18. Name four oxidative processes occurring in mitochondria for cellular respiration.

Ans. (i) Krebs tricarboxylic acid cycle, (ii) β -oxidation of fatty acids, (iii) Electron transport system and (iv) oxidative phosphorylation.

19. Where do the folloning occur in mitochondria?

(a) TCA cycle, (b) β Oxidation of fatty acids, (c) electron transport system and (d) oxidative phosphorylation.

Ans. (a) and (b): In mitochondrial matrix.

(c) In the inner membrane of cristae.

(d) In the F particles of cristae.

20. What is the main difference between the cisternae of endoplasmic reticulum and Golgi body ?

Ans. The cisternae of endoplasmic reticulum are rough surfaced due to the presence

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of ribosomes on their surface whereas the cisternae of Golgi body are smooth surfaced as they are devoid of ribosomes.

21. In which cytoplasmic organelles do you find the following structures:

(a) cristae, (b) Fernandez-Moran particles, (c) mitoribosomes, (d) grana, (e) centriole, (f) blepharoplast, (g) tonoplast, (h) cisternae?

Ans. (a), (b), (c): Mitochondria. (d) Chloroplast, (e) Centrosome. (f) Cilia and flagella. (g) Vacuole. (h) Endoplasmic reticulum and Golgi body.

22. Name three cyloplasmic inclusions present in—(a) animal cells and (b) plant cells.

Ans. (a) Glycogen, Zymogens, Fat globules. (b) Starch grains, Cystolith, Raphides.

23. What are the main chemical constituents of—(a) cell membrane, (b) cell wall, (c) ribosomes, (d) microtubules, (e) microfilaments, (f) cystoliths, (g) raphides and (h) nuclear reticulum?

Ans. (a) Lipid and protein. (b) Cellulose, hemicellulose, pectin, lignin, suberin ctc. (c) Ribosomal RNA and protein. (d) A protein called tubulin. (e) Proteins called actin, myosin, tropomyosin, tropomin and α-actinin. (f) Calcium carbonate. (g) Calcium oxalate. (h) DNA and protein.

24. State with reasons whether the cell membrane is a living or non-living structure.

Ans. The cell membrane is a living structure because: (i) it is selecticly permeable, (ii) it acts as a barrier and (iii) its permeability varies with change in temperature, ionic concentration and pH of the surrounding medium.

25. Why cell wall is considered as a dead (non-living) structure?

Ans. Cell wall is considered as a non-living structure because it is totally permeable and it cannot act as a barrier.

26. Name two mammalian cells in which nucleus is located peripherally.

Ans. Adipose tissue cell, skeletal muscle cell.

27. Name two animal cells containing more than one nuclei.

Ans. Paramoecum (protozoa) and skeletal muscle cell.

28. What do you mean by primitive nucleus and true nucleus?

Ans. The nucleoid of prokaryotic cells is called primitive nucleus which is not covered by a membrane separating it from the cytoplasm. The nucleus of eukaryotic cells is called true nucleus which is clearly distinguishable from the cytoplasm and contains four parts in nuclear membrane, nucleoplasm, nuclear reticulum and nucleolus.

29. What is cell-sap?

Ans. Cell-sap is the fluid present within a vacuole.

30. What are karyotheca and karyoplasm?

Ans. Karyotheca is the double layered membranous covering of nuleus *i.e.* the nuclear membrane. Karyoplasm is the fluid matrix of nucleus, also known as nucleoplasm.

31. What are rhodoplasts, phaeoplasts, xanthoplasts and carotenoplasts?

Ans. Chromoplasts having red, brown, yellow and orange colours (pigments) are called rhodoplasts, phaeoplasts, xanthoplasts and carotenoplasts respectively.

32. What change would you observe in the colour of green leaves of a young living plant if they are deprived of sunlight for some days? Give reason.

Ans. On being deprived of sunlight, the green leaves would become colourless (white) due to transformation of chloroplasts into leucoplasts.

33. Explain with reason why the colour of a green (unripe) mango changes to

yellow on ripening.

Ans. During ripening, the chloroplasts (green coloured plastids) present in the cells of skin of a green mango are transformed into xanthoplasts (yellow coloured chromoplasts), so the colour of mango changes from green to yellow

34. Name the : (a) smallest cell, (b) largest cell, (c) longest animal cell and

(d) longest plant cell.

Ans. (a) Mycoplasma, (b) 1 gg of ostrich (c) Mammalian neurone (d) Phloem fibres of Ramie plant.

35. Mention two characters by which you can identify a cell as plant cell.

Ans. (i) Presence of cell wall and (ii) presence of plastid

36. Which cells contain a single large vacuole?

Ans. Matured plant cells.

37. Which type of enzymes are found in—(a) lysosomes and (b) mitochondria? Ans. (a) Hydrolytic enzymes, (b) Oxidative enzymes

• [C] Multiple choice type questions :

1. Cellular components are physically separated from each other by-

(a) Microscopy. (b) Chromatography, (c) Homogenisation and centrifugation, (d) Radioactive tracers.

2. Which structure of a plant cell is most closely associated with energy conversion reactions of aerobic respiration?

(a) Nucleus, (b) Ribosome, (c) Mitochondria, (d) Chloroplast.

3. The diameter of the high-power field of a microscope is 1 mm. The diameter of a cell which would fill the field would be—

(a) 1μm, (b) 10 μm, (c) 100 μm (d) 1000 μm.

4. Which structure of animal cell is characterized by selective permeability?

(a) Ribosome, (b) Chromosome, (c) Cell membrane, (d) Cell wall

5. Which cellular structure is found in the epidermal cells of humans but not in the epidermal cells of leaves?

(a) Mitochondition, (b) Cell membrane, (c) Centriole (d) Chloroplast.

6. Cell membrane is composed mainly of-

(a) Protein and sugar, (b) Lipid and protein, (c) Starch and lipid, (d) Sugar and minerals.

7. Which structure carries out a similar function in both plant and animal cells?

(a) Centrosome, (b) Cell wall, (c) Chloroplast (d) Cell membrane.

8. The size of most of the cells is best expressed in units of-

(a) Metres, (b) Centimetres, (c) Micrometres, (d) Inches.

9. The chief constituent of cytoplasm is-

(a) Protein, (b) Lipid, (c) Carbohydrate, (d) Water.

10. Animal cells requiring large amount of energy have relatively large number of—

(a) Chloroplasts, (b) Mitochondria, (c) Golgi bodies, (d) Ribosomes.

11. Which structure controls transport of materials into and out of living cells?

(a) Cell wall, (b) Endoplasmic reticulum, (c) Golgi bodies, (d) Cell membrane.

- 12. Which structure is present in prokaryotic cells as well as eukaryotic plant and animal cells. ?
 - (a) Cell wall, (b) Ribosome, (c) Chloroplast, (d) Mitochondrion.
 - 13. Which of the following contains electromagnetic lenses?
- (a) Simple microscope, (b) Compound microscope, (c) Phase contrast microscope, (d) Eletron microscope.
 - 14. The internal structure of chloroplast is best studied with the help of-
- (a) Compound microscope, (b) Phase contrast microscope, (c) Scanning electron microscope, (d) Transmission electron microscope.
 - 15. Mitochondria were first observed in skeletal muscle by-
 - (a) Robert Brown, (b) Robert Hooke, (c) Altmann (d) Kolliker.
 - 16. Which pair of structures are found in both plant and animal cells?
- (a) Nucleus and cell wall, (b) Nucleolus and cell membrane, (c) Cell wall and cell membrane, (d) Nucleolus and contractile vacuoles.
 - 17. A plant cell usually differs from an animal cell in the absence of-
 - (a) Mitochondria, (b) Endoplasmic reticulum, (c) Centriole, (d) Ribosome.
 - 18. Physical basis of life is-
 - (a) Cell, (b) Nucleus, (c) Food, (d) Protoplasm.
 - 19. Cell theory states that-
- (a) All cells are living, (b) All cells have nuclei, (c) (ells reproduce by mitosis and meiosis. (d) Cells are structural units of plants and animals.
 - 20. True nucleus is not found in-
 - (a) Green algae, (b) Fungi, (c) Bacteria, (d) Protozoa.
 - 21. The cell organelle having electron transport system is —
 - (a) Ribosome, (b) Lysosome, (c) Centrosome, (d) Mitochondrion.
 - 22. The chief chemical constituent of middle lamella is-
 - (a) Lignin, (b) Pectin, (c) Suberin, (d) Cellulose.
 - 23. The chief constituent of cell wall is a-
 - (a) Carbohydrate, (b) Protein, (c) Lipid, (d) Salt.
- 24. Continuity of cytoplasm between adjacent plant cells is maintained through—
- (a) Plasmalemma, (b) Plasmodesmata, (c) Middle lamella, (d) Endoplasmic reticulum.
 - 25. Stroma is the ground substance of-
 - (a) Mitochondria, (b) Cytoplasm, (c) Chloroplast (d) Nucleus.
 - 26. Cytoplasm contains water-
 - (a) Upto 25%, (b) Upto 50%, (c) Upto 75%, (d) More than 75%.
 - 27. Which of the following organelle is rich in oxidative enzymes?
 - (a) Endoplasmic reticulum, (b) Mitochondria, (c) Lysosome, (d) Chloroplast.
 - 28. Bacteria are-
 - (a) Protozoa, (b) Prokaryotes, (c) Eukaryotes, (d) Mesokaryotes.
 - 29. Ribosomes are made up of-
 - (a) DNA and RNA, (b) DNA and protein, (c) RNA and protein, (d) only RNA
 - 30. Ribosome is the site of-
 - (a) Fat synthesis, (b) Respiration, (c) Protein synthesis, (d) Photosynthesis.

- 31. Golgi body originates from-
- (a) Endoplasmic reticulum, (b) Cell membrane, (c) Cytoplasm, (d) Nuclear membrane.
 - 32. Plasmagel is the name of-
 - (a) Protoplasm, (b) Cytoplasm, (c) Ectoplasm, (d) Endoplasm.
 - 33. The photosynthetic units of chloroplasts are called--
 - (a) Glyoxysomes, (b) Spherosomes, (c) Microsomes, (d) Quantosomes.
 - 34. The non-living ergastic substances are also known as-
 - (a) Mesoplasm, (b) Deutoplasm, (c) Hyaloplasm, (d) Kinoplasm.
 - 35. Which of the following is lysosome of plant cells?
 - (a) Spherosome, (b) Peroxisome, (c) Glyoxysomes, (d) Microsome.
 - 36. Sarcoplasmic reticulum is a modified form of —
- (a) Smooth endoplasmic reticulum, (b) Rough endoplasmic reticulum, (c) Nuclear reticulum, (d) Golgi-tubule.
 - 37. Which of the following is not found in an intact cell?
 - (a) Dictyosome, (b) Microsome, (c) Polysome, (d) Lysosome.
 - 38. Polyribosome means-
- (a) A group of ribosomes, (b) A pair of ribosomes, (c) Mitochondrial ribosomes, (d) A group of ribosomes linked with a mRNA.
 - 39. A lysosome digesting engulfed food material is called—
 - (a) Autophagosome, (b) Primary lysosome, (c) Heterophagosome, (d) Kinetosome.
 - 40. When a lysosome engulfs an old and inactive cell organelle, it forms.—
 - (a) Autophagosome, (b) Diplosome, (c) Secondary lysosome. (d) Primary lysosome
 - 41. In which one of the following DNA is absent?
 - (a) Chloroplasts, (b) Mitochondria, (c) Peroxisome, (d) Nucleus.
 - 42. Elaioplasts store— .. *** *** ****
 - (a) Carbohydrates. (b) Protein, (c) Oils (d) Minerals.
 - 43. Nucleolus is rich in-
 - (a) DNA, (b) RNA, (c) DNA and RNA, (d) DNA, RNA and protein.
 - 44. Cells having larger nuclei in proportion to cytoplasm are—
 - (a) Dividing, (b) Active, (c) Dying (d) Inactive.
 - 45. Besides nucleus DNA is also found in-
 - (a) Chloroplast, (b) Endoplasmic reticulum, (c) Golgi body, (d) Ribosome.
 - 46. Contractile vacuoles are concerned with-
 - (a) Digestion, (b) Respiration, (c) Excretion, (d) Photosynthesis.
- 47. The sketch of cork cells as observed by Robert Hooke was published in the book—
 - (a) Micrographia, (b) Origin of species, (d) Plant kingdom, (d) None of these.
- 48. Which of the following cytoplasmic organelles is essential for photorespiration?
 - (a) Endoplasmic reticulum, (b) Peroxisome, (c) Glyoxysome, (d) Dictyosome.
 - 49. Plasmalemma is composed of-
- (a) Cellulose and hemicellulose, (b) Phospholipids and hemicellulose, (c) Phospholipids, extrinsic proteins and intrinsic proteins. (d) Phospholipids and integral proteins.

- 50. Ribosomes of prokaryotic cells are of-
- (a) 55S type, (b) 70S type, (c) 80S type, (d) 100S type.
- 51. The maximum magnification obtained by electron microscope is—
- (a) 250 times, (b) 2500 times, (c) 25000 times, (d) 250000 times or more.
- 52. The subunits of 80S ribosomes are—
- (a) 60S and 40S, (b) 50S and 30S, (c) 40S and 40 S, (d) 35S+25S.
- 53. The most vital centre of a cell is-
- (a) Mitochondrion, (b) Plastid, (c) Cell membrane, (d) Nucleus.
- 54. Which of the following helps in cell division?
- (a) Golgi body, (b) Centrosome, (c) Ribosome (d) Lysosome.
- 55. Middle lamella is a part of—
- (a) Cell membrane, (b) Cell wall, (c) Nuclear membrane, (d) Mitochondrial membrane.
 - 56. Which of the following is an ergastic substance of animal cells?
 - (a) Starch, (b) Glycogen, (c) Cellulose, (d) Tanin.
 - 57. The two centrioles of a centrosome are together called—
 - (a) Polysome, (b) Diplosome, (c) Kinetosome, (d) Microsome.
 - 58. Quantosomes remain within-
 - (a) Leucoplasts, (b) Chloroplasts, (c) Chromoplasts, (d) Tonoplast.
 - 59. In which part of a chloroplast, are the photosynthetic enzymes present?
 - (a) Grana, (b) Stroma, (c) Stroma lamellae, (d) Outer membrane.
- 60. Which one of the following is stored as a secretory ergastic substance in a cell?
 - (a) Aleurone, (b) Starch, (c) Zymogen, (d) Latex.

Answers to Q. C

[1] Homogenisation and centrifugation. [2] Mitochondria. [3] 1000 µm. [4] Cell membrane. [5] Centriole. [6] Lipid and protein. [7] Cell membrane. [8] Micrometres. [9] Water. [10] Mitochondria. [11] Cell membrane. [12] Ribosome. [13] Electron microscope. [14] Transmission electron microscope. [15] Kolliker. [16] Nucleolus and cell membrane [17] Centriole. [18] Protoplasm. [19] Cells are structural units of plants and animals. [20] Bacteria. [21] Mitochondrion. [22] Pectin. [23] Carbohydrate [24] Plasmodesmata. [25] Chloroplast [26] More than 75%. [27] Mitochondria. [28] Prokaryotes. [29] RNA and protein. [30] Protein synthesis. [31] Endoplasmic reticulum. [32] Ectoplasm. [33] Quantosomes. [34] Deutoplasm. [35] Spherosome. [36] Smooth endoplasmic reticulum. [37] Microsome. [38] A group of ribosomes linked with a mRNA. [39] Heterophagosome. [40] Autophagosome. [41] Peroxisome. [42] Oils. [43] DNA, RNA and protein.

- [44] Active. [45] Chloroplast. [46] Excretion. [47] Micrographia. [48] Peroxysome.
- [49] Phospholipids, extrinsic proteins and intrinsic proteins. [50] 70S type.
- [51] 250,000 times or more. [52] 60S and 40S. [53] Nucleus. [54] Centrosome.
- [55] Cell wall. [56] Glycogen. [57] Diplosome. [58] Chloroplasts. [59] Stroma.
- [60] Zymogen.

Chapter 3: Cell Function

• [A] Distinguish between:

1. Distinguish between water potential (ψ_{ω}) and diffusion pressure deficit (DPD) of a solution.

Ans.

Water potential (ψ_{ω})	Diffusion pressure deficit (DPD)			
(1) Ψ_{ω} of a solution means the	(i) DPD of a solution means the			
difference between the free energy of	difference between the DP of pure			
water molecules in pure water and the	solvent and the DP of solvent molecules			
solution.	in the solution.			
(ii) It is inversely proportional to the	(ii) DPD of a solution is directly			
concentration of the solution.	proportional to the concentration of the			
	solution.			
(iii) It has a negative value.	(iii) It has a positive value			
(iv) In osmosis, water molecules flow	(iv) In osmosis, water molecules			
from higher ψ_{ω} to lower ψ_{ω} .	move from lower DPD to higher DPD.			

2. Distinguish between pressure potential (ψ_p) and solute potential (ψ_s) of a solution.

Ans.

Pressure potential (ψ _p)	Solute potential (ψ _s)		
(i) It refers to turgor pressure or	(i) It refers to reduction of water		
hydrostatic pressure.	potential due to presence of solutes in a solution.		
(ii) It is proportional to the amount of	(ii) It is proportional to the amount of		
water present in a solution.	solutes in a solution.		
(iii) It has a positive value.	(iii) It has a negative value.		

3. Distinguish between ion channels and ion pumps.

Ans.

Ion channels	Ion pumps		
(i) These are transmembrane proteins (i.e. membrane proteins that penetrate through the entire thickness of a membrane).	(i) These are membrane proteins that can move freely within the lipid matrix of a membrane.		
(ii) They act as selective pores for diffusion (passive transport) of ions across the membrane.	(ii) They act as carriers (not pores) for active transport of ions across the membrane.		

• [B] Short answer type questions :

1. Why diffusion is called a passive process?

Ans. Diffusion is a passive process because it is driven by the inherent random motion of the diffusing particles and no external energy or force or pressure is required for it.

2. Which one among a solid, a liquid and a gas can diffuse most rapidly and why?

Ans. A gas can diffuse more rapidly than a liquid or a solid, because the inherent molecular motion is maximum in gases.

3. Can a gas diffuse through—(a) cell membrane, (b) vacuum?

Ans. (a) Yes, (b) Yes.

4. Through which of the following, would a gas diffuse most rapidly and why? (a) air, (b) a liquid, (c) vacuum.

Ans. A gas would diffuse much more rapidly through vacuum because in this case, the motion of the diffusing molecules would not be interfered by any other molecule. But in case of diffusion of a gas through air or a liquid, migration of the diffusing molecules is interrupted due to their collision with the molecules of air or the liquid.

5. What is diffusion pressure? How is it related to diffusion?

Ans. Diffusion pressure (DP) is the pressure exerted by the diffusible particles which is directly proportional to their concentration. DP is the driving force for diffusion, in which particles migrate from a region of higher concentration having higher DP to a region of lower concentration where the DP is lower. Thus, diffusion occurs due to the difference in DP between the two regions.

- 6. Specify the types of the following membranes, based on their permeability:
- (a) a thin polythene sheet, (b) a cellophane paper, (c) a cell membrane, (d) a heavily cutinised cell wall, (e) a cellulose cell wall, (f) a fish bladder.

Ans. (a) Impermeable, (b) Semi-permeable, (c) Selectively permeable, (d) Impermeable, (e) Permeable, (f) Semi-permeable.

7. Explain why osmosis is referred to as a special type of diffusion.

Ans. Diffusion means migration of gaseous, liquid or solid particles from a region of higher concentration to a region of lower concentration. On the other hand, osmosis is a phenomenon in which the solvent molecules flow from a solution of lower concentration to a solution of higher concentration when the two solutions are separated by a semi-permeable membrane. A semi-permeable membrane allows only the solvent molecules to pass through its pores.

In osmosis, only the solvent molecules pass through the pores of the semi-permeable membrane from the side having greater number of solvent molecules (*i.e.* less concentrated solution) to the side having fewer number of solvent molecules (*i.e.* more concentrated solution). Thus, osmosis is a special type of diffusion in which solvent molecules diffuse through a semi-permeable membrane.

8. Explain whether osmosis is an active process or passive process.

Ans. Osmosis is a passive process because in this, the solvent molecules of a solution migrate towards a more concentrated solution through a semi-permeable membrane by the process of diffusion which does not require any external force or pressure and it is driven by the inherent motion of the solvent molecules.

9. How long will the osmosis continue if a concentrated aqueous solution of sugar is kept separated from water by a semi-permeable membrane?

Ans. osmosis will continue till the hydrostatic pressure of the solution becomes high enough to prevent further entry of water molecules into it, *i.e.* the hydrostatic pressure and osmotic pressure of the sugar solution become equal to counter balance each other.

10. How long will osmosis continue if two aqueous solutions of sugar having different concentrations are kept separated by a semi-permeable membrane?

Ans. In this case, osmosis will continue till a condition of equilibrium is reached when the concentration of two solutions becomes equal or the hydrostatic pressure of the more concentrated solution becomes equal to its osmotic pressure.

11. What is deplasmolysis?

Ans. If a plasmolysed plant cell (i.e. a plant cell in which the protoplasm has contracted and receded from the cell wall due to exosmosis) is placed in hypotonic solution or distilled water, the cell regains its turgidity due to endosmosis. This phenomenon of reversal of plasmolysed state in a plant cell is called deplasmolysis.

12. What is diffusion pressure deficit or DPD of a solution? How is it related to osmosis?

Ans. Diffusion pressure deficit (DPD) of a solution is the difference between the diffusion pressure (DP) of pure solvent and the DP of solvent in the solution.

Higher the concentration of a solution, greater is its DPD. In osmosis, solvent molecules move from the solution having lower DPD to the solution having higher DPD.

13. What is water potential of a solution? How is it related to osmosis?

Ans. The difference between the free energy of water molecules in pure water and a solution is termed as water potential of the solution. Higher the concentration of a solution, the lesser is its water potential. In osmosis, water molecules flow from a solution having higher water potential (i.e. less concentrated) to a solution having lower water potential (i.e. more concentrated).

14. Why is the diffusion pressure deficit (DPD) also called suction pressure (SP)?

Ans. DPD of a solution is also called SP because higher the DPD of a solution, greater is its ability to draw or suck water by osmosis.

15. A and B are two adjoining plant cells where osmotic movement of water can occur. Cell A has an osmotic pressure (OP) of 18 atm and turgor pressure (TP) of 10 atm, whereas cell B has an OP of 10 atm and TP of 6 atm. Find out the direction of flow of water between these two cells.

Ans. As the diffusion pressure deficit (DPD)=OP – TP, the cell A has a DPD of 18-10=8 atm and the cell B has a DPD of 10-6-4 atm. Since water moves from lower DPD to higher DPD, the flow of water will be from cell B (DPD = 4 atm) to cell A (DPD = 8 atm).

16. A and B are two adjoining living plant cells where osmotic movement of water can occur. In cell A, the osmotic potential or solute potential $(\psi_s) = -20$ bars and pressure potential $(\psi_p) = +18$ bars, whereas in cell B, the $(\psi_s) = -12$ bars and $(\psi_p) = +4$ bars. Determine the direction of flow of water between the two cells.

Ans. We know that water potential $(\psi_{\omega}) = (\psi_{s}) + (\psi_{p})$.

:. In cell A, $\psi_{\omega} = -20$ bars + 18 bars = -2 bars.

In cell B, $\psi_{0} = -12$ bars + 4 bars = -8 bars.

Since water moves from higher ψ_{ω} to lower ψ_{ω} , the flow of water will be from cell A ($\psi_{\omega}=-2$ bars) to cell B ($\psi_{\omega}=-8$ bars).

17. What occupies the space between the protoplasm (or plasmalemma) and the cell wall when a plant cell is plasmolysed by placing it in a hypertonic solution? Explain.

Ans. In a plasmolysed plant cell, the space between the protoplasm (or plasmalenima) and the cell wall remains occupied by the external hypertonic fluid because the cell wall is freely permeable to water and solutes.

18. What do you mean by 'turgidity' and 'flaccidity' of plant cells?

Ans. Turgidity of a plant cell refers to the extent to which the cell is turgid *i.e.* inflated by water due to the entry of water into the cell by endosmosis. It is denoted by turger pressure (TP) or pressure potential (ψ_p) Full turgidity *i.e.* maximum TP or ψ_p of a cell is attained when the cell is placed in pure water. At full turgidity, the ψ_p of a cell becomes equal to its solute potential (ψ_s) ; thus the water potential (ψ_ω) of the cell becomes zero and no further water can enter into it.

Flaccidity of a plant cell refers to a state when protoplasm does not exert any pressure on the cell wall i.e. when TP or ψ_p is minimum (zero) and the ψ_ω of the cell becomes equal to its ψ_s , as in a cell at incipient plasmolysis or in a fully plasmolysed cell.

19. What will happen if pure water is transfused in a patient instead of normal (isotonic) saline?

Ans. If pure water is transfused into a patient's body, the water may pass into the tissues and also cause hemolysis (rupture of blood cells) due to endosmosis, producing fatal results.

20. What is the difference of water potential ψ_ω in a fully turgid cell and a fully flaccid cell ? What is its significance ?

Ans. In a fully turgid cell, the water potential is maximum (zero); so no further water is allowed to enter into the cell even if it is placed in pure water.

Conversely, in a fully flaccid cell, the water potential is minimum; so water can readily enter into the cell when the cell is placed in a hypotonic solution or pure water.

21. What will happen to the DPD (diffusion pressure deficit) of a cell when its starch content is converted to sugar? Explain.

Ans. When the starch content of a cell is converted to sugar, the DPD of the cell will increase. This is because starch is insoluble in water and hence osmotically inactive, whereas sugar being soluble in water, is osmotically active. Increase in sugar content of a cell leads to rise in solute concentration and osmotic pressure (OP) in the cell. As DPD is directly proportional to OP, DPD of the cell will also rise.

22. What do you mean by osmoregulation?

Ans. Osmoregulation means regulation of osmolarity of body fluid in an animal by regulating the solutes and water content of the body fluids.

23. What are osmoconformers and osmoregulators?

Ans. Osmoconformers are animals which do not have the osmoregulatory ability and can tolerate a wide variation of osmolarity of body fluids occurring due to variation in the osmolarity of the ambient medium.

Osmoregulators are animals which cannot tolerate a wide variation of osmolarity of body fluids and have the ability to maintain the osmolarity of their body fluids within a narrow range, different from the surrounding medium in which they live.

24. What type of urine is excreted by the fresh water fishes and why?

Ans. Fresh water fishes excrete a large volume of dilute urine in order to retain salts

in the body and excrete the excess water from the body for osmoregulation, as they have to maintain their body fluid hypertonic to the surrounding medium.

25. What are ionocytes? What is their importance?

Ans. Ionocytes are specialised cells present in the gill membrane of fishes which help in active absorption or pumping out of monovalent ions like Na⁺, Cl etc. In fresh water fishes, they help to absorb ions from the surrounding water for maintaining hypertonicity of their body fluid. Conversely, in marine fishes, the ionocytes help to pump out ions from the body fluid to maintain the body fluid hypotonic to sea water.

26. What are osmolytes? What is their importance?

Ans. Osmolytes are organic compounds like urea, trimethylamine oxide (TMAO) etc. which are accumulated in the body fluid of sharks living in sea water. These substances raise the the osmolarity of body fluid and help in osmoregulation by preventing loss of water from the body fluid that might have occurred due to high salinity of the sea water.

27. When an animal cell is kept in 0.5 M solution of sucrose, its volume does not alter. What will happen if the same cell is placed in 0.5 M solution of NaCl?

Ans. As the NaCl is an ionisable solute, 0.5 M NaCl solution will exert more osmotic pressure than 0.5 M sucrose solution. So the cell will show exosmosis and decrease in volume when it is placed in 0.5 M NaCl solution.

• [C] Multiple choice type questions:

1. Diffusion means-

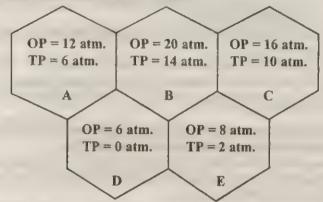
- (a) Movement of molecules from one place to another.
- (b) Random movement of molecules.
- (c) Tendency of molecules to distribute themselves evenly within the space they occupy.
- (d) Passage of water molecules from a dilute to concentrated solution through a semi-permeable membrane.
- 2. If a bottle of perfume is kept open, its odour spreads all around. It is an example of diffusion of—
 - (a) Liquid in gas. (b) Liquid in liquid. (c) Gas in liquid. (d) Gas in gas.
 - 3. In case of a gas, diffusion is driven by-
- (a) Concentration gradient. (b) Pressure gradient. (c) Electrical gradient. (d) Temperature gradient.
 - 4. Osmosis may be defined as movement of water molecules—
- (a) Into the root hair cells. (b) From a concentrated solution to dilute solution. (c) From a concentrated solution to a dilute solution through a semi-permeable

membrane. (d) From a dilute solution to a concentrated solution through a semipermeable membrane.

5. Osmosis occurs when-

- (a) Two solutions are mixed.(b) Two solvents are mixed.(c) Two gases are mixed.(d) Two solutions of differnt concentrations are separated by a semi-permeable membrane
- 6. In a plasmolysed cell, the space between the cell wall and cell membrane is occupied by—
 - (a) Air. (b) Water. (c) A hypotonic solution. (d) The external hypertonic solution.

- 7. When a living all is placed in hypertonic solution-
- (a) Exosmosis takes place. (b) Endosmosis takes place. (c) No osmosis takes place. (d) The cell swells up.
 - 8. Which of the following has the highest water potential?
 - (a) Milk. (b) 20% sugar .at. in (c) 20% salt solution. (d) Distilled water.
- 9. The diagram given below shows osmotic pressure (OP) and turgor pressure (TP) of adjoining plant cells A, B, C, D, and E.



If the TP of cell B increases to 16 atm, what change in water movement would occur?

- (a) Cells A, C, D, E will absorb water from cell B. (b) Water will diffuse into cell B from other cells. (c) No movement of water will take place. (d) Cell B will actively absorb water from other cells.
- 10. "Osmosis means diffusion of a solution of weaker concentration into a solution of higher concentration, when the two solutions are separated by a semi-permeable membrane." What is the error in this statement?
- (a) The behaviour of semi-permeable membrane is not specified. (b) There is no mention of DPD. (c) The movement of water (solvent) molecules is not specified. (d) The exact concentration of the solutions are not mentioned.
 - 11. A cell increases in volume if its surrounding medium is-
- (a) Hypertonic. (b) Hypotonic. (c) Isotonic. (d) Much more concentrated than the protoplasm of the cell.
- 12. When a plant cell is placed in a hypotonic solution, which of the following conditions will not apply?
- (a) The cell will become turgid. (b) The water potential of cell sap will rise. (c) The wall pressure of cell will fall. (d) The suction pressure of cell sap will fall.
 - 13. In osmosis, solvent molecules flow from the solution of-
- (a) Lower concentration to the solution of higher concentration. (b) Higher concentration to the solution of lower concentration. (c) One cell to another. (d) None of these.
- 14. If cell A with OP=5 atm and TP=4 atm is surrounded by other cells with Op=5 atm and TP=2 atm, what will be the direction of water movement?
- (a) From other cells to cell A. (b) From cell A to other cells. (c) There will be no water movement. (d) None of these.
 - 15. When a cell is fully turgid, which of the following will be zero?
 - (a) Turgor pressure. (b) Wall pressure, (c) Osmotic pressure, (d) Suction pressure.

16. If a plant cell is immersed in water, water will continue to enter into the cell until the—

(a) Concentration of salt inside the cell becomes same as outside (b) Diffusion pressure of water inside the cell becomes same as outside. (c) Cell bursts (d) Amount of water inside the cell is same as outside.

17. DPD stands for-

(a) Diffusion potential deficit. (b) Diffusion pressure deficit. (c) Daily photosynthetic demand. (d) Daily phosphate demand.

18. The outward pressure exerted by protoplasm on the cell wall in a state of tension is called—

(a) Osmotic pressure (b) Root pressure. (c) Turgor pressure. (d) Wall pressure.

19. Deplaymolysis occurs in a plant cell when the cell is dipped in-

(a) Isotonic solution. (b) Hypotonic solution. (c) Hypertonic solution. (d) None of these.

20. If the cell wall is elastic instead of being rigid and the cell is put in a sugar solution of higher concentration than that of the cell, then—

(a) The cytoplasm will shrink away from the wall. (b) The cell wall as well as cytoplasm will shrink. (c) The cell wall will break up as the cytoplasm shrinks. (d) The size and shape of the cell will not change.

21. If a fish bladder is partially filled with syrup, tightly tied and immersed in water—

(a) The volume of liquid within the bladder decreases. (b) The volume of liquid within the bladder increases. (c) The volume of liquid within the bladder remains same. (d) Plasmolysis will occur.

22. The direction and rate of water movement from cell to cell is determined by—

(a) Turgor pressure. (b) Wall pressure. (c) Incipient plasmolysis. (d) Diffusion pressure deficit.

23. Water will be absorbed by root hairs when-

(a) The plant is rapidly respiring. (b) The concentration of solutes in the cell sap is high. (c) The root hair membrane is permeable to both water and solutes. (d) Concentration of solutes in the soil is high.

24. According to their permeability, the cell wall and cell-membrane are-

(a) Both semi-permeable (b) Permeable and differentially permeable respectively. (c) Both differentially permeable. (d) Semi-permeable and differentially permeable respectively.

25. The water potential of pure water is-

(a) Minimum. (b) Zero. (c) Less than zero. (d) More than zero.

26. Solute potential is the-

(a) Water potential. (b) Turgor pressure. (c) Osmotic potential. (d) Pressure potential.

27. Pressure potential refers to-

(a) Osmotic pressure. (b) Turgor pressure. (c) Solute potential. (d) Water potential.

28. Passive transport may require—

(a) Carrier. (b) Energy (c) Enzyme. (d) All of the above.

29. Active transport requires-

(a) Carrier. (b) Energy. (c) Both carrier and energy. (d) Neither carrier nor energy.

30. Ion channels of cell membrane are proteins that act as-

(a) Carriers. (b) Enzymes. (c) Receptors. (d) Pores.

31. A cell absorbs diffusible ions passively due to the-

(a) Concentration gradient. (b) Pressure gradient. (c) Osmotic gradient. (d) Electrical gradient.

32. Ion pumps help in-

- (a) Active absorption of sugars. (b) Passive absorption of sugars. (c) Active absorption of electrolytes. (d) Passive absorption of ions.
 - 33. Unicellular animals perform osmoregulation with the help of-

(a) Ion channels. (b) Ion pumps. (c) Contractile vacuoles. (d) Osmosis.

34. Marine bony fishes swallow-

(a) Food only. (b) Sea water only. (c) Both food and sea water. (d) Neither food nor sea water.

35. Fresh water bony fishes swallow-

(a) Food only. (b) Water only. (c) Both food and water. (d) Neither food nor water.

36. The body fluids of fresh water animals are-

(a) Isotonic to the surrounding medium. (b) Hypertonic to the surrounding medium. (c) Hypotonic to the surrounding medium. (d) None of these.

37. The body fluid of a marine bony fishes is-

(a) Isotonic to sea water. (b) Hypertonic to sea water. (c) Hypotonic to sea water. (d) None of these.

38. Fresh water bony fishes usually excrete—

(a) A small volume of dilute urine. (b) A small volume of concentrated urine.

(c) A large volume of dilute urine. (d) A large volume of concentrated urine

39. The kidneys of fresh water bony fishes retain-

(a) Salts mainly. (b) Water mainly. (c) Both salt and water. (d) None of these.

40. TMAO is an-

(a) Ion channel. (b) Ion pump. (c) Ionocyte. (d) Osmolyte.

Answers to O. C

[1] Tendency of molecules to distribute themselves evenly within the space they occupy. [2] Gas in gas. [3] Pressure gradient. [4] From a dilute solution to a concentrated solution through a semi-permeable membrane. [5] Two solutions of different concentrations are separated by a semi-permeable membrane. [6] The external hypertonic solution. [7] Exosmosis takes place. [8] Distilled water. [9] Cells A,C,D, E will absorb water from cell B. [10] The movement of water (solvent) mobecules is not specified. [11] Hypotonic. [12] The suction pressure of cell sap will fall. [13] Lower concentration to the solution of higher concentration. [14] From cell A to other cells. [15] Suction pressure. [16] Diffusion pressure of water inside the cell becomes same as outside. [17] Diffusion pressure deficit. [18] Turgor pressure [19] Hypotonic solution. [20] The cell wall as well as cytoplasm will shrink. [21] The volume of liquid within the bladder increases. [22] Diffusion pressure deficit. [23] The concentration of solutes in the cell sap is high, [24] Permeable and differentially permeable respectively. [25] Zero. [26] Osmotic potential. [27] Turgor pressure. [28] Carrier. [29] Both carrier and energy. [30] Pores. [31] Electrical gradient. [32] Active absorption of electrolytes. [33] Contractile vacuoles. [34] Both food and sea water. [35] Food only. [36] Hypertonic to surrounding medium. [37] Hypotonic to sea water. [38] A large volume of dilute urine. [39] Salts mainly. [40] Osmolyte.

Chapter 4: Enzymes

• [A] Short answer type questions:

1. Who first proposed—(a) the term enzyme, (b) the lock and key (or template) hypothesis of enzyme action, (c) the induced fit hypothesis of enzyme action, (d) that enzymes are proteins?

Ans. (a) Kuhn. (b) Emil Fischer. (c) Koshland. (d) Sumner.

2. (a) Which enzyme was first discovered and by whom? (b) Which enzyme was first isolated in pure (crystallized) form and by whom?

Ans. (a) The first discovered enzyme was Zymase which was discovered by Eduard Buchner. (b) Urease was the first enzyme isolated in pure (or crystalized) form by Sumner.

3. What is holoenzyme?

Ans. A conjugate protein type enzyme consisting of a protein part (or apoenzyme) and a non-protein part (coenzyme or prosthetic group) is called holoenzyme.

4. What is a multienzyme system? Give two examples.

Ans. An enzyme containing more than one active sites on the same protein macromolecule (apoenzyme) for catalysing different consecutive reactions is designated as a multienzyme system. Examples pyruvic dehydrogenase, fatty acid synthase.

5. Why enzymes are called biological catalysts (or biocatalysts)?

Ans. Enzymes are called biological catalyst (or biocatalysts in short) because they are protein molecules produced by living cells and they act as catalysts in biochemical reactions (i.e. chemical rections occurring in a biological systems) by reducing the activation energy of the reactions.

6. What are endoenzymes and exoenzymes?

Ans. In a living body, those enzymes which act within the cells of their origin are called endoenzymes whereas those acting outside the cells of their origin are called expenzymes.

7. What do you mean by specificity of enzymes?

Ans. Specificity of enzymes refers to the fact that enzymes are highly specific in their action. Some enzymes are so specific that they can catalyse only one reaction by acting on a particular substrate; this is called **absolute specificity**. Example—lactase can hydrolyse lactose only but not other disaccharides. On the other hand, some enzymes can catalyse a particular kind of reactions, *i.e.* they can act on a particular class of substrates; this is called **group specificity**. Example—pepsin and trypsin can act on different proteins to digest them.

8. (a) What do you mean by optimum temperature for an enzyme? (b) What is the optimum temperature of mammalian enzymes?

Ans. (a) The temperature at which the activity of an enzyme is maximum is called optimum temperature for the enzyme. The rate of enzyme action gradually declines both above and below this temperature level.

- (b) The optimum temperature of mammalian enzymes ranges between 37—40°C.
- 9. Explain the effects of very low and very high temperatures on the activity of enzymes.

Ans. Enzymes are inactivated at both very low and very high tempertures. At a very

low temperature, the enzyme proteins are frozen and their molecular motion (Brownian movement) ceases, thereby preventing their binding with the substrates; thus the enzymes fail to work. However, this inactivation due to freezing is **temporary** and the enzymes may regain their activity on raising the temperature.

On the other hand, at a very high temperature, inspite of the increased molecular motion, enzymes are inactivated **permanently** due to denaturation of their protein structure. Such a denatured enzyme does not regain its activity on lowering the temperature.

10. What is meant by temperature coefficient or Q_{10} for an enzyme controlled reaction ?

Ans. The temperature coefficient or Q_{10} represents the effect of temperature on the rate of a reaction. Q_{10} is defined as the ratio by which the rate of a reaction changes due to 10° C rise of temperature.

Therefore,
$$Q_{10} = \frac{\text{Rate of reaction at } (x + 10)^{\circ} \text{C}}{\text{Rate of reaction at } x^{\circ} \text{C}}$$

Over a range of 0-40°C, Q₁₀ for an enzyme controlled reaction is 2. That means, the rate of an enzyme controlled reaction is doubled for every rise of 10°C.

11. Can any enzyme remain active at a temperature of 70°C or more? If so, give example and mention its significance.

Ans. Although most of the enzymes are denatured and inactivated above 50°C, there are some enzymes which remain active and have an optimum temperature of 70°C or more. Examples of this are the enzymes of bacteria living in hot springs having such a high temperature. If these enzymes were inactivated by the temperature of the hot springs, those bacteria could have not survived in such springs.

12. (a) What is meant by optimum pH for an enzyme? (b) Name an enzyme having optimum pH-(i) 2, (ii) 9.

Ans. (a) The pH at which an enzyme shows maximum activity is called optimum pH for that enzyme. The rate of enzyme activity gradually diminishes with alteration of pH above or below the optimum level.

(b) (i) Pepsin. (ii) Pancreatic lipase.

13. 'All enzyme molecules are proteins'. What is its importance in enzyme action?

Ans. As all enzymes are proteins, their molecules are colloidal particles showing Brownian movement (continuous, random zig-zag movement). Such movement helps in collision between enzyme and substrate molecules and thereby formation of enzyme-substrate complex, which is necessary for enzyme action.

14. Mention the similarity and difference in the actions of the enzymes grouped as oxidases and dehydrogenases.

Ans. Similarity: Both oxidases and dehydrogenases catalyse oxidation reactions.

Difference: Oxidases help in oxidation of a substrate by adding oxyden to it, whereas dehydrogenases help in oxidation of a substrate by removing hydrogen atoms from it.

15. Distinguish between the enzymes grouped as lyases and ligases.

Ans. Lyases are enzymes which catalyse reactions involving removal of a group from a substrate or addition of a group to a substrate without hydrolysis, oxidation and reduction. On the other hand, *ligases* are enzymes which catalyse linking of two compounds by energy consuming reaction.

16. What change do you expect in the rate of an enzyme catalysed reaction if the substrate concentration is raised in presence of a—(i) competitive inhibitor and (ii) non-competitive inhibitor?

Ans. (1) The rate of reaction will increase. (11) The rate of reaction will not change.

17. What are allosteric inhibitors of enzyme action?

Ans. Allosteric inhibitors are low molecular weight compounds which can bind to an enzyme at a site other than its catalytic (active) site so that the active site is denatured and the substrate binding and catalytic ability of the enzyme is lost

18. What are allosteric activators of enzyme action?

Ans. Allosteric activators are low molecular weight compounds which bind to a non-catalytic site of an enzyme to increase the substrate binding and catalytic ability of the enzyme.

19, 'Feed back inhibition of enzyme is a kind of allosteric inhibition'. Justify the statement.

Ans. Feed back inhibition of enzyme means inhibition of an enzyme by a product of a reaction series involving the enzyme. In this case, as the product is different from the substrate of the affected enzyme, it obviously inhibits the enzyme by binding to a non-catalytic (allosteric) site of the enzyme. Thus, feed back enzyme inhibition is nothing but a kind of allosteric inhibition.

20. What is the physiological significance of feedback inhibition of an enzyme? Ans. Feed back inhibition of an enzyme helps in self-regulation of a metabolic pathway to prevent unnecessary accumulation of products.

• [B] Multiple choice type questions :

- 1. All enzymes are chemically-
- (a) Carbohydrates. (b) Proteins (c) Lipids (d) None of these.
- 2. The protein part of an enzyme is called-
- (a) Apoenzyme. (b) Coenzyme. (c) Holoenzyme. (d) Cofactor.
- 3. An organic cofactor which remains firmly bound to an apoenzyme is called-
- (a) Coenzyme. (b) Prosthetic group. (c) Isoenzyme. (d) Proenzyme.
- 4. Many vitamins act as-
- (a) Antienzymes. (b) Proenzymes. (c) Coenzymes. (d) Enzymes.
- 5. Enzymes differ from inorganic catalysts in-
- (a) Having a high diffusion rate. (b) Not being used up in reactions. (c) Being proteinaceous in nature. (d) Working at high temperature.
 - 6. Which of the following is not a character of enzymes?
- (a) They are specific in catalytic activity. (b) They increase the speed of biochemical reactions. (c) They are chemically protein in nature. (d) They are used up in the reactions.
 - 7. Which of the following is not a property of an enzyme?
- (a) They are sensitive to temperature. (b) They decrease the activation energy of a reaction. (c) They can be used repeatedly. (d) They are not sensitive to pH.
 - 8. That 'enzymes are proteins' was suggested by-
 - (a) Pasteur. (b) Buchner. (c) Fischer. (d) Sumner.
 - 9. Which of the following facts support the template theory of enzyme action?
 - (a) Enzymes act as catalysts. (b) Enzymes determine the direction of reactions.

- (c) Compounds similar in structure to the substrate may inhibit the reaction. (d) Enzymes are proteins.
 - 10. At boiling temperature most of the enzymes are-
 - (a) Activated. (b) Inhibited. (c) Denatured. (d) Unaffected.
 - 11. Pepsin is-
 - (a) A proenzyme. (b) An endoenzyme. (c) An exoenzyme. (d) A coenzyme.
 - 12. A competitive inhibitor of an enzyme is a-
- (a) Product analogue. (b) Substrate analogue. (c) Irreversible inhibitor. (d) Allosteric inhibitor.
 - 13. The enzymes catalysing addition of oxygen to a substrate are grouped as—
 - (a) Oxygenases. (b) Oxidases. (c) Dehydrogenases. (d) Lyases.
 - 14. The enzymes amylase and lipase are—
 - (a) Hydrolases. (b) Lyases. (c) Isomerases. (d) Ligases.
 - 15. All enzymes are—
- (a) Secreted by living cells. (b) Produced by living cells. (c) Active within living cells only. (d) Conjugated proteins.
 - 16. In competitive inhibition of enzyme action, the inhibitor binds with the-
- (a) Catalytic site of the enzyme. (b) Non-catalytic site of the enzyme. (c) Substrate. (d) Product.
 - 17. An allosteric inhibitor of enzyme action acts by combing with the-
- (a) Catalytic site of the enzyme. (b) Non-catalytic site of the enzyme. (c) Substrate. (d) Product.
 - 18. Which of the following may cause feedback inhibition of an enzyme?
 - (a) Substrate analogues. (b) Metal ions. (c) Poisons. (d) Products.
 - 19. Which of the following is essential for action of all enzymes?
- (a) Optimum pH. (b) Optimum temperature. (c) Presence of cofactors. (d) Binding of substrate to the enzyme.
 - 20. Trypsinogen is-
 - (a) A proenzyme. (b) A coenzyme. (c) An endoenzyme. (d) An exoenzyme.

Answers to Q. B -

[1] Proteins. [2] Apoenzyme. [3] Prosthetic group. [4] Coenzymes. [5] Being proteinaceous in nature. [6] They are used up in the reactions. [7] They are not sensitive to pH. [8] Summer. [9] Compounds similar in structure to the substrate may inhibit the reaction. [10] Denatured [11] An exoenzyme. [12] Substrate analogue. [13] Oxidases. [14] Hydrolases. [15] Produced by living cells. [16] Catalytic site of the enzyme. [17] Non-catalytic site of the enzyme. [18] Products. [19] Binding of substrate to the enzyme. [20] A proenzyme.

Chapter 5: Chromosome

• [A] Long answer type questions :

1. How is karyotype and idiogram prepared?

Ans. The shoot tip or the root tip is pretreated with glacial acetic acid and boiled with aceto-orcein stain. It is then spread on a slide using squashing technique. The metaphase stage is identified in a cell with all the chromosomes visible clearly. A photograph is taken or a camera lucida sketch is made, which represents the karyotype of the organism. The chromosomes are then cut off from the photograph or the camera lucida sketch and arranged on a graph paper on the descending order of their size. The latter forms the idiogram.

2. What is the importance of centromere in a chromosome?

Ans. The unstained portion of a metaphase chromosome is called primary constriction or centromere. The centromere contains 4 granular chromosomes, two being attached to the chromonemata. The central portion contains a plate-like structure called kinetochore. There are some specific points on the kinetochore called MTOC or microtubule organization centre. The microtubules of the spindle fibres get attached to these points and they undergo depolymerization resulting in the anaphasic separation of the chromosomes.

3. What are exon and intron? What are their functions?

Ans. The functional gene sequences in a chromatin thread are called exon, while the intervening sequences are called introns. The exons are responsible for metabolic functions including protein synthesis. But the introns are repetative sequences that are usually spliced off during the formation of m-RNA. Hence they do not take part in protein synthesis, but they separate two functional genes from each other.

4. What is operon? What are its different types?

Ans. Operon model was denoted by Jacob and Monod (1961) in prokaryotic system. Operon actually consists of different types of genes broadly differentiated as master genes and slave genes. The master genes include the inducer gene, operator gene, promoter gene, while the slave genes include the structural genes.

Two major types of operons have been designated in prokaryotic and eukaryotic systems. They are the repressor-inducer system and the apo-repressor, co-repressor system. The repressor-inducer system is found in **lactose operon**, where the system is switched off due to the production of the repressor molecule. It binds to the operator site and switches off the system. The lactase molecule acts as a de-repressor and whenever it is added to the medium, it de-represses the depressor molecule and the system is switched on and lactose molecule is produced.

The apo-repressor-co-repressor system is found in case **tryptophan** operon. The system is mitially switched on because the apo-repressor produced by the repressor gene did not block the operator site fully. The end product tryptophan is produced, it acts as a co-repressor and along with the apo-repressor molecule, it blocks the operator site fully. Thus the system is switched off and the phenomenon is called feed back inhibition.

5. Why is Z-DNA important?

Ans. Z-DNA was denoted by Sashi Shekharan et. al. from the LLSc. Bangalore in

1983. It is a left handed DNA with a right handed tilt, which gives a zig-zag pattern. The helical diameter is 18Å and axial rise of 3.70Å. The number of nitrogen bases is also highest (12) amongst all the types of DNA molecules.

6. State the major steps of DNA replication.

Ans. The replication of DNA is semi-conservative in nature and the major steps are as follows:

- (i) All the nucleotides are converted to their respective triphosphate forms.
- (ii) The replication is initiated at the point of nick appearance by endonuclease enzyme.
- (iii) The unwinding of the DNA double helix takes place with the help of helicase enzyme.
- (iv) The replication bubbles are formed at several points of the DNA double helix due to the action of topoisomerase.
- (v) A short RNA primer is formed at the point of origin of replication, which is 200 nucleotide long under the action of DNA dependent RNA polymerase.
- (vi) The DNA fragment is attached to the 3' end of the RNA primer under the action of DNA polymerase III.
- (vii) The RNA primer is replaced by a short DNA fragment under the action of DNA polymerase I.
 - (viii) Joining of the 2 strands of DNA by DNA ligase to form the leading strand.
- (1x) The synthesis of smaller RNA fragments on the other strand along with small DNA fragments (upto 1000 bases long) called **Okazaki fragments**, commonly called lagging strand.
 - (x) Joining of the DNA frangments by polynucleotide ligase.
 - (xi) Rejoining of DNA strands and formation of the coiled DNA double helix.
 - 7. What is hn RNA? How is it modified to m-RNA?

Ans. The hn RNA is produced from the DNA by the synthesis of the template strand through complementary base recognition. But it contains large number of repetitive sequences. It forms the functional m-RNA in the following way:

- (i) The repetitive sequence forms a loop and that is spliced off.
- (ii) After splicing, the cut ends are rejoined by ligase.
- (iii) The polyadenine tail is attached at the 3' end.
- (iv) The methyl cap is formed at the opposite end. Thus the m-RNA is ready to be transported to the cytoplasm.
 - 8. What is genetic code? What are the different properties of genetic code?

Ans. The method by which the nitrogen bases are arranged on the m-RNA in triplet fashion is known as *genetic code*. The genetic code is dependent on the structure of DNA and it controls protein synthesis.

The properties of genetic code are:

- (i) It is universal from virus to man.
- (ii) The code consists of 3 nitrogen bases.
- (iii) The code is degerate, i.e. more than one codon can code for one amino acid.
- (iv) It can also be ambigous, i.e. one codon can code for more than one ammo acid.
- (v) The codon is commaless.
- (vi) The codon is non-overlapping.

(vii) The first codon is AUG, which usually codes for methionine and initiates protein synthesis.

(viii) The last codon is any one of the three, i.e. UGA, UAA and UAG, which do

not code for any amino acid and is referred to as non-sense codon.

9. What is the role of ribosome in protein synthesis?

Ans. The mbosomes provide the site for protein synthesis. After the m-RNA comes to the cytoplasm, the smaller unit of the ribosome (30S or 40 S) gets attached with it and later with the help of Mg²⁺ ion, the bigger subunit (50S or 60S) also binds with it. There are 2 different sites of the bigger ribosome, viz. P site and A site known as the peptidyl site and amino-acyl site. The presence of AUG codon at the P site attracts the methionine t-RNA and that initiates protein synthesis. Then the second successive t-RNA comes to the A site and a peptide linkage is produced between the two amino acids. In this way the elongation of the polypeptide chain takes place as the ribosome moves to the opposite side of the m-RNA. Ultimately the appearance of non-sense codon at the A site terminates protein synthesis.

10. What are the different types of RNA? Briefly describe their structures.

Ans. RNA are mainly of 3 types, viz. m-RNA, t-RNA and r-RNA.

m-RNA: The m-RNA is formed from DNA by the process template synthesis, it is devoid of introns, it contains a polyadenine tail at the 3' end and a methyl cap at the opposite end. The first codon is AUG, which initiates polypeptide synthesis and the last one is a non-sense codon, which terminates protein synthesis.

t-RNA: It is a highly folded structure consisting of certain double stranded regions. The open end has double CCA terminal that binds with the amino acid. The opposite end has an anticodon, the two lateral loops are DHU and TψC. The entire structure is very much similar to a clover leaf.

r-RNA: They are variable in size, single stranded, linear with some double stranded regions. They aggegrate to form larger subunits, which ultimately forms the ribosome and thereby the site for protein synthesis is formed.

11. Give the brief description of a metaphase chromosome.

Ans. The chromosome matures at metaphase. Each chromosome has two major parts, i.e. centromere or primary constriction and chromatid. The centromere may be present at any portion of the chromosome and the spindle fibres get attached to it during the chromosomal division. When the centromere is at the centre of the chromosome, it is called metacentric, when it is close to the centre, it is submetacentric, when it is close to the terminal end, it is called telocentric chromosome. Some chromosomes may have the secondary constriction, close to the terminal end with the nucleolus organization region attached to it. There may be a bulge of chromatid present beyond the secondary constriction called satellite, which is devoid of DNA. The telomere is at the terminal end of the chromosome, which prevents joining of 2 chromosomes. The entire chromosome may have rounded coils associated with histone protein called chromomere. The chromatid chromomeres are larger in size, more in number but centromeric chromomeres are small and four in number.

12. What are autosomes and allosomes?

Ans. The chromosomes which have similar structure in both male and female organism and control vegetative characters are known as *autosomes*, while the

chromosomes which are different in male and female are called allosomes or sex chromosomes, which determines sex in higher organisms; e.g. human male or female has 22 pairs of autosome, in male it is XY chromosomes and in human female it is XX chromosome.

13. What are irregular chromosomes?

Ans. The chromosomes which are not present in normal type of cells and take part in some specific metabolic functions are known as irregular chromosomes and they are of the following types:

- (i) B chromosome or Super numerary chromosome.
- (ii) L Chromosome or limited chromosome present in a specific sex.
- (iii) M-chromosome: They are so called because of their nucroscopic size.

S and E chromosome: S chromosomes are found in both somatic cells and reproductive cells of certain insects, but E chromosomes are only found in the reproductive cells and not in the somatic cells.

14. How can you classify chromosomes on the basis of the position of the centromere?

Ans. On the basis of the position of the centromere, a chromosome can be divided into 4 major types:

- (i) Metacentric or Isobranchial: The centromere is located at the centre of the chromosome, so the two arms of the chromosomes are equal in size.
- (ii) Submetacentric or heterobranchial: The centromere is not located at the centre of the chromosome, so the two areas of the chromosome slightly differ in size.
- (iii) Acrocentric: The centromere is located very close to the terminal end of the chromosome, so one arm of the chromosome is very small and the other is very large.
- (iv) Telocentric: The centromere is located at the terminal end, so there is only one single arm, instead of two arms. Present day scientists do not believe in the existence of this type of chromosome.

15. What is meant by euchromatin and heterochromatin? [J.E.E. 1987]

Ans. The euchromatin and heterochromatin are formed due to unequal coiling of the chromatin fibres within the nucleus. In the interphase stage, the lightly stained region of the chromatin are called euchromatin, which consists of functional genes. In the same stage, the dark stained regions of the chromatin are called heterochromatin, which remains in a condensed state during resting state and is devoid of functional genes. Heterochromatin can be of 2 types, the one which remain in condensed state at all stages of cell cycle are called constitutive heterochromatin, while the one which do not remain in condensed state at all stages of cell cycle is called facultative heterochromatin.

16. What is nucleosome?

Ans. The chromatin fibres of the nucleus of a living cell is composed of histone protein and DNA. The total thickness of DNA fibril is 190.4\AA and it remains in coiled state around 8 histone core proteins, 4 on each side. These globose histone core units are H_{2A} , H_{2B} , H_3 and H_4 and they are arranged on both sides of the cylindrical histone.

core unit called H_1 . The DNA fibril are wounded around the globose units by $1\frac{3}{4}$ th turn. These histone protein units along with the surrounding DNA fibril together is called nucleosome octamer.

17. What is residual chromosome?

Ans. A chromosome consists of 90% of deoxy-ribonucleoprotein, which has 45% DNA and 55% histone protein. The remaining 10% of a chromosome is called residual chromosome. It has 2-3% DNA, 12-14% RNA and 84-86% non-histone protein.

18. What is meant by puff and Balbiani ring?

Ans. The upper part of a polytene chromosome shows large number of light and dark rings. The dark rings are called bands and the regions in between these dark bands are called interbands. The swollen regions in between two rings are called puffs. Sometimes these puffs may form external ring-like outgrowths called Balbiani rings. These puffs and Balbiani rings consist of excess DNA and RNA, which helps in the synthesis of extra proteins.

19. What is meant by monoploidy and monosome conditions?

Ans. When a particular organism even in matured state remain in Exploid condition, it is called monoploid. e.g. certain ferns.

When an organism consists of one chromosome less than its normal diploid number (2n-1), it is called monosomic. This organism is formed by the fusion of 'n' and 'n-1' gamete e.g. Turner syndrome in man (44A + X0).

20. What are triploid and trisomic condition?

Ans. When a particular organism has 3 times the halploid number of chromosome, it is called triploid (3n). These types of plants are artificially produced because they become seedles and thereby the economic importance of the fruit increases, e.g. Banana. Whan a particular organism has one extra chromosome, in addition to its normal diploid number (2n + 1), it is called a trisomic. It is formed by the fusion of 'n' and 'n + 1' gamete, e.g. Klinefelter syndrome in man (44A + XXY).

21. What are the features of B-DNA?

Ans. The DNA molecule described by Watson and Crick is actually the B-DNA.

- (i) It is slightly tilted towards right.
- (ii) It has a double stranded helical structure and each strand is made up of deoxyribose sugar and phosphoric acid.
 - (iii) The strands are joined by nitrogen bases.
 - (iv) Each major turn has a distance of 34Å.
 - (v) There are 10 base pairs in between two major turns.
 - (vi) The distance between each base pair is 3.4Å.

22. Which nitrogen base is absent in DNA? State the number of hydrogen bonds in between nitrogen bases. What is Chargaff's rule?

Ans. The DNA molecule is devoid of Uracil. In a DNA molecule, there are 3 hydrogen bonds between guanine and cytosine and 2 hydrogen bonds between adenine and thymine. The chargaff's rule states that the ratio between adenine: thymine and

guanine : cytosine will always be 1 : 1, i.e.
$$\frac{A}{T} = 1$$
, $\frac{G}{C} = 1$ and $\frac{A + G}{T + C} = 1$.

23. State the functions of RNA.

Ans. m-RNA: It carries the information from nucleus to cytoplasm and controls the process of polypeptide synthesis.

hn-RNA: The m-RNA in its initial stage of formation is known as hn-RNA, which on maturity gives m-RNA.

t-RNA: The t-RNA carries the amino acid depending on its specific anticodon and carries it towards m-RNA codon for polypeptide synthesis.

r-RNA: It forms the ribosome and there by provides the space for protein synthesis.

24. How the RNA molecules help in protein synthesis? [J.E.E. 1990]

Ans. The m-RNA, r-RNA and t-RNA have their specific roles in protein synthesis. m-RNA: It carries the genetic code from the nucleus to the cytoplasm and there by determines the sequence of amino acids in the polypeptide.

r-RNA: The smaller units of r-RNA aggregate with each other to form the larger subunits, which finally join to each other and provide the site for protein synthesis.

t-RNA: It joins with the specific amino acid on the basis of the anticodon present with the help of ATP and draws it towards m-RNA (codon) during protein synthesis.

• [B] Distinguish between:

1. What are the differences between DNA and RNA? Ans.

[J.E.E. 1990]

DNA					
(i) DNA	is a double	stranded			
molecule.					
(ii) DNA	mainly remains	within the			

- nucleus and also within the mitochondria and chloroplastid of a living cell.
- (iii) The different types of DNA are B-DNA, C-DNA, A-DNA, Z-DNA.
- (iv) The DNA molecule has deoxyribose sugar.
- (v) The four nitrogen bases are adenine, guanine, thymine and cytosine.
- (vi) The DNA forms RNA by transcription.
 - (vii) It is the true genetic material.

RNA (i) RNA is a single stranded molecule.

- (ii) RNA remains in the nucleus and cytoplasm.
- (iii) The different types of RNA are m-RNA, r-RNA, t-RNA and hn-RNA.
- (iv) The RNA molecule has ribose sugar.
- (v) The four nitrogen bases are adenine, guanine, uracil and cytosine.
- (vi) RNA of retro virus can form DNA by reverse transcription.
- (viii) It is not the genetic material in majority of organisms.

2. Distinguish between chromosome and chromatid. Ans.

(i) The chromosomes are formed by the breaking of chromatin reticulum.

Chromosome

- (ii) Chromosome consists of chromatid and centromere.
- (iii) The chromosome divides at the anaphase of cell division.
- (iv) Chromosome is large and behaves as unit of heredity.

Chromatid

- (i) Chromatid is the thread like elongated portion of chromosome.
- (ii) The chromatid consists of chromonema and chromomere.
- (iii) The chromatid divides at the end of prophase.
- (iv) Chromatid is smaller in size and is a part of chromosome.

3. Distinguish between centromere and chromomere.

Ans.

		Cen	tron	iere	
		-	-		
1.	card.		. I		

- (i) The part of chromosome, which does not divide during metaphase.
- (ii) It is bigger in size and usually one in number in a chromosome.
- (iii) It can remain anywhere within the chromosome, or sometimes it can be in diffused state.
- (iv) It gets attached to the spindle fibre during cell division.
- (v) It is formed mainly of heterochromatin and less euchromatin.

Chromomere

- (i) The globular protein molecules distributed all along the chromosome.
- (ii) It is smaller in size and four chromomeres remain within each centromere.
- (iii) It is distributed in the chromatid and centromere.
- (iv) It never gets attached to the spindle fibres.
- (v) It is mainly formed of euchromatin.

4. Distinguish between DNA and m-RNA.

Ans.

DNA

- (i) The molecule is double stranded.
- (ii) The components of DNA are 2deoxyribose sugar, phosphoric acid and nitrogen base.
- (iii) The nitrogen bases are adenine, guanine, thymine and cytosine.
- (iv) DNA is the actual genetic
- (v) DNA has repetitive and non-repetitive sequences.
- (vi) DNA produces m-RNA by transcription.

m-RNA

- (i) The molecule is single stranded.
- (ii) m-RNA is formed of ribose sugar, phosphoric acid and nitrogen base.
- (iii) The nitrogen bases are adenine, guanine, uracil and cytosine.
- (iv) m-RNA is not the true genetic material.
- (v) m-RNA is devoid of repetitive sequences.
- (vi) m-RNA in very rare occasions form DNA by reverse transcription in certain viruses.

5. Distinguish between centriole and centromere.

Ans.

Centriole

- (i) It is only present in animal cell and lower plant cell.
- (ii) In general, there are two centrioles present; during cell division, four centrioles are formed.
- (iii) Each centriole is formed of triplet microfibrils.
- (iv) It forms spindle fibres with astral rays and also helps in flagellary movement.

Centromere

- (i) It is present in the chromosome of higher plant and animal cell.
- (ii) In general, there is one centromere in each chromosome; rarely there may be two or many centromeres.
- (iii) Each centromere is formed of four chromomeres.
- (iv) It helps in the attachment of chromosome with spindle fibres and there by helps in its replication.

• [C] Short answer type questions:

1. What is muton?

[J.E.E. 1999]

Ans. The functional unit of DNA nucleotide that is capable of showing mutation is known as muton.

2. Where from the name DNA has originated?

[J.E.E. 2000]

Ans. The sugar molecule of DNA belongs to 2-deoxy ribose and hence the name deoxyribonucleic acid is given.

3. Who first proved the DNA double helix model?

[J.E.E. 2000]

Ans. J. D. Watson and F.H.C. Crick (1953).

4. Why chromosome is named such?

[J.E.E. 2000] -

Ans. The chromosome is stained deeply with basic stain (chroma ≡ colour; soma ≡ body), hence the name chromosome is given.

5. Name the pyrimidine bases of DNA.

[J.E.E. 2001]

Ans. Thymine and Cytosine.

6. Which eukaryotic organelle has DNA?

Ans. Mitochondria and chloroplastid.

7. What is perinuclear space?

Ans. The intermediate space inbetween the two membranes of nucleus is called perinuclear space, its breadth can be 100-700Å.

8. In which state of cell cycle, nuclear membrane is absent? [J.E.E. 1987]

Ans. In the cell cycle, the nuclear membrane disappears from the end of prophase, up to the late telophase.

9. What is genome?

Ans. The total number of genes present in the haploid number of chromosomes of a gamete of an organism is known as genome.

10. What is Barr body?

Ans. The second X chromosome of higher mammals including man becomes heterochromatinized and remain as a dense, refractile chromatin body near the nuclear membrane, inside the nucleus. This is known as Barr body after the name of its discoverer M. Barr. It does not perform any function.

11. What is telomere?

Ans. The terminal part of each chromosome is known as telomere. It prevents the attachment of one chromosome to other.

12. What is the position of the centromere in holocentric chromosome?

Ans. The centremeres are distributed on the entire chromosome in holocentric chromosome.

13. What is kinetochore?

Ans. The plate like component of centromere, that gets attached to the spindle fibres, is known as kinetochore.

14. What is chromonemata?

Ans. The thread-like component of chromatid which remain in a highly coiled state is known as chromonemata. Each chromatid at least has 2 chromonemata (sing. chromonema).

15. State the number of chromatin fibres in a polytene chromosome.

Ans. A single polytene chromosome may have 512 to 2048 chromatin fibres, usually it is 1024.

16. Which hormone stimulates puffing in chromosome?

Ans. The ecdysone hormone of insects stimulates the formation of puffs in a chromosome.

17. Which chromosome shows loop formation? What is its function?

Ans. The loops are present in lampbrush chromosomes. Its main function is to synthesize excess RNA and protein.

18. What is nuclein?

Ans. Nuclein is considered to be the unit of chromosome, consisting of nucleic acid and protein.

19. What is polynucleotide chain?

Ans. The DNA molecule is composed of two spiral strands and each of the strands are composed of many nucleotide, so they are termed as polynucleotide chain.

20. What are the distances between the nitrogen bases of opposite strands of a DNA molecule?

Ans. In a DNA molecule, the distance between adenine and thymine of opposite strands is 11.1Å, while that between guanine and cytosine is 10.8Å.

21. What is the breadth of DNA molecule?

Ans. The breadth of the DNA molecule is 20Å.

22. Who proposed the lateral (sideways) model of DNA?

Ans. The lateral or sideways model of DNA was proposed by Hopkins (1981).

23. What is codon?

Ans. The three introgen bases of 3 nucleotides arranged laterally on the m-RNA is known as codon. Each codon codes for an amino acid and helps in the synthesis of polypeptide.

24. Where is anticodon located

Ans. The anticodon is located on the t-RNA.

25. What is the first codon of a m-RNA during protein synthesis?

Ans. The first codon of m-RNA during polypeptide synthesis is AUG, which codes for methionine and initiates protein synthesis. In rare cases it can be GUG coding for valine.

26. What are the terminating codons? Why are they called nonsense codons?

Ans. The terminating codons are UAG, UGA and UAA. They are also called nonsense codons because they do not code for any amino acids.

27. Which enzyme is called genetic knife?

Ans. The enzyme endonuclease is called genetic knife.

28. Which enzyme helps in m-RNA synthesis.

Ans. The enzyme DNA dependent RNA polymerase helps in m-RNA synthesis.

29. How many types of grooves are there in a DNA molecule?

Ans. There are two types of grooves in a DNA molecule. The deep groove or major groove and the shallow groove or minor groove.

30. What are super numerary chromosomes?

Ans. In certain plant and animal ceils, in addition to the normal chromosomes, there may be additional chromosomes which do not take part in phenotypic expression and are termed as extra or supernumerary chromosomes.

31. Where is polytene chromosome found?

Ans. Polytene chromosomes are mainly found in the salivary gland of insect larvae.

It is also present in the wall of anterior and mid alimentary canal and in the wall of malpighian tubule.

32. Where is puff found? What is its function?

Ans. Puffs are swollen regions found along the entire length of polytene chromosomes.

It stores huge amount of RNA and protein.

33. What is allocycly.

Ans. The heterochromatin portion of a chromosome during the interphase remains in a highly coiled state, so they take up deep stain. But in the metaphase substage, the coiling is reduced, so they take up less stain. This phenomenon of variable staining of heterochromatin is called allocycly.

34. What are plectonemic and paranemic coiling?

Ans. The chromonemata within a chromosome shows two types of coiling. When they remain in a spirally coiled state, it is called plectonemic coil, while if they are arranged in parallel state, it is called paranemic coiling.

35. What is linker DNA?

Ans. The DNA thread in between two histone core protein molecules of a nucleosome octamer having a restriction endonuclease recognition site is known as linker DNA. This type of DNA has 60 pairs of nucleotide.

36. What is solenoid?

Ans. In general the diameter of a nucleosome fibre of a chromosome is 110Å, but because of repeated coiling, they form a fibril of 300Å called solenoid. The solenoid may sometimes get super coiled forming super solenoid.

37. What is chromosome backbone?

Ans. When the histone protein is removed from chromosome, then the non-histone core of the chromsome is termed as chromosome backbone. Its lateral portion is attached to the DNA fibre.

38. What is heteropycnosis?

Ans. The chromosome has two major portion called euchromatin and heterochromatin. They are coiled in ununiform manner in various stages of the cell cycle and hence take up light and dark stain. This phenomenon of unequal staining of the chromosome in different stages of the cell cycle is termed as heteropycnosis.

39. What are prochromosomes?

Ans. In the interphase stage of a living cell, the chromosomes remain as narrow coiled threads and are distributed in the nucleoplasms without any separate entity. These coiled threads give rise to chromosomes in the prophase and they are termed as prochromosomes.

40. What are polyploids?

Ans. The physiological process by which the chromosomes increase or decrease in size is known as polyploidy and the organisms are termed as polyploids.

Polyploids are of two major types, euploids and aneuploids. In case of euploids, the chromosomes multiply by their entire set, but in case of aneuploids, the diploid chromosome number increases or decreases by one or two chromosomes.

41. What are the different nitrogenous bases of DNA?

Ans. The four different nitrogen bases of DNA are adenine, guanine, thymine and cytosine. Adenine and guanine are purine bases, while thymine and cytosine are pyrimidine bases.

42. How the two DNA strands are antiparallel?

Ans. The two DNA strands are antiparallel to each other, that is if one strand extends from 5' to 3' end, then the other strand will be from 3' to 5' end. That is if the 5th carbon of the pentose sugar is attached to one strand, than the other strand will be attached to the 3rd carbon of the pentose sugar.

43. What is cistron?

Ans. A functional fragment of gene is called cistron. Usually the number of nucleotides present in a gene is three times the number of amino acids it can recognize.

44. What is satellite DNA?

Ans. A living cell only utilizes 5-10% of its DNA in the formation of codon, the remaining 90% DNA is actually repetitive in nature. As for example, in a chromosome, near its primary constriction, there are 10 nucleotides with nearly 1000 times repetitions. These are called satellite DNA, which does not take part in m-RNA transcription but completes the DNA structure.

45. What are dominant and recessive genes?

[J.E.E. 1986]

Ans. In a pair of homologous chromosomes, out of a pair of gene remaining in heterozygous condition, at the same locus, one is always expressed and is known as the dominant gene, while the other which is never expressed is known as recessive gene. Example—in sweat pea plant, tallness is controlled by dominant gene and dwarfness is controlled by recessive gene.

46. What is primary constriction?

[J.E.E. 1987]

Ans. The distinct unstained part of a chromosome which gets attached to the spindle fibre and helps in division of the chromosome is called primary constriction. It is usually one or two in number, but in some cases (as in *Luzula*) is distributed in the entire chromosome. It is formed of 4 distinct chromomeres and may be distributed at any portion of the chromatid and depending upon its position on the chromatid, it can be classified into various types.

- [D] Multiple choice type questions :
- 1. DNA structure denoted by Watson & Crick was
- (a) B-DNA (b) D-DNA (c) C-DNA (d) Z-DNA.
- 2. The model of DNA showing right handed helix is
- (a) B-DNA (b) C-DNA (c) Z-DNA (d) D-DNA
- 3. Deletion usually results in the production of
- (a) acentric fragment (b) dicentric fragment (c) polycentric fragment (d) satellite.
- 4. The extranuclear DNA attached to bacterial genome are called
- (a) plasmid (b) episome (c) vector (d) Satellite DNA.
- 5. The cap produced in m-RNA includes
- (a) ethyl group (b) methyl group (c) formyl group (d) phenyl group.
- 6. The number of centromeric chromomeres are
- (a) 2 (b) 4 (c) 6 (d) 8.
- 7. The non-sticky nature of the chromosome are provided by
- (a) centromeric chromomere (b) telomere (c) chromatid chromomere (d) satellite.
- 8. The part of a chromosome devoid of DNA is
- (a) satellite (b) chromonema (c) primary constriction (d) secondary constriction.

- 9. The activity of protein synthesis in an operon is carried out by
- (a) promoter gene (b) operator gene (c) structural gene (d) repressor gene.
- 10. The apo repressor can operate in a
- (a) lactose operon, (b) tryptophan operon.
- 11. The C bands are enriched in
- (a) A = T residue (b) $G \equiv C$ residue (c) constitutive heterochromatin (d) facultative heterochomatin.
 - 12. The technique involved in DNA fingerprint is
 - (a) Southern blot (b) PCR (c) both.
 - 13. The bread wheat is
 - (a) diploid (b) triploid (c) tetraploid (d) hexaploid in nature.
 - 14. The number of base pairs per turn of ZDNA is
 - (a) 8 (b) 10 (c) 12 (d) 9.
 - 15. The number of base pairs present in Linker DNA is
 - (a) 40 (b) 50 (c) 60 (d) 70.
 - 16. The nullo-X syndrome is the other name for
 - (a) Turner syndrome (b) Klinefelter syndrome (c) Downs syndrome.
 - 17. The configuration of sex chromosomes in a super male is
 - (a) XXY (b) YYY (c) XYY (d) OY.
 - 18. The first gene to be synthesized artificially was
 - (a) GGG (b) UUU (c) UUG (d) GUU.
 - 19. The first amino acid to be coded during protein synthesis is
 - (a) methionine (b) valine (c) either methionine or valine.
 - 20. The nature of the protein protamine in chromosome is
 - (a) acidic (b) basic (c) neutral.
 - 21. The total number of possible codons are
 - (a) 16 (b) 48 (c) 64 (d) 72.
 - 22. The number of genes present in man are
 - (a) Around 60,000 (b) Around 72,000 (c) Around 25000.
 - 23. The r-RNA are produced from
 - (a) nucleus (b) nucleolus (c) chromatin.
 - 24. The clover leaf model is used to denote
 - (a) r-RNA (b) t-RNA (c) m-RNA.
 - 25. The phenomenon of reverse transcription is observed in
 - (a) RNA virus (b) DNA virus (c) Bacteria.
 - 26. The m-RNA is the matured form of
 - (a) t-RNA (b) r-RNA (c) hn-RNA.

Answers to Q. D

- [1] B-DNA. [2] Z-DNA. [3] acentric fragment. [4] episome. [5] methyl-group.
- [6] 4. [7] telomere. [8] satellite. [9] structureal gene. [10] tryptophan operon.
- [11] constitutive heterochromatin. [12] both. [13] hexaploid in nature. [14] 12.
- [15] 60. [16] Turner syndrome. [17] XYY. [18] UUU. [19] either methionine or valine. [20] basic. [21] 64. [22] around 25,000. [23] nucleolus. [24] t-RNA.
- [25] RNA virus. [26] hn-RNA.

Chapter 6: Cell Division

[A] Long answer type questions:

1. What is spindle apparatus? What are the different types of spindle fibres present there?

Ans. The aggregation of spindle fibres present in a dividing cell from prophase to telophase between the north pole and south pole of the cell is known as spindle apparatus.

It has the following types of fibres:

- (i) Continuous fibres: During the formation of spindle fibres, those fibres which are continuous between the two poles of a cell are known as continuous fibres.
- (ii) Interzonal fibres: During the anaphase substage of cell division, the spindle fibres formed in between the chromosomes moving towards the opposite poles are known as interzonal fibres.
- (iii) Chromosomal fibres: The spindle fibres that are yet attached to the chromosomes during the anaphase substage of nutosis are known as chromosomal fibres or tactic fibres.
- (iv) Astral fibres: In a dividing animal cell, the smaller fibres that remain attached to the centriole is known as astral fibres.

2. How does cytokinesis take place in animal cell?

Ans. After the karyokinesis or division of nucleus is completed, the equatorial plane of the cell shows the formation of two lateral constrictions. Along these constrictions, the actin and myosin fibres are accumulated, which causes chemical change within the cell and the constrictions gradually move inwards through those fibres and the cell is divided into two. This method is also termed as furrowing.

3. How does cytokinesis take place in plant cell?

Ans. At the end of karyokinesis in a plant cell, the pectic substances along with dictyosomes are deposited in the equatorial plane to form the phragmoplast or cell plate, which ultimately forms the middle lamella and divides the cell into two. The deposition of cellulose and hemicellulose on the middle lamella forms the primary wall, while the deposition of lignin and suberin on the primary wall forms the secondary wall.

4. What is synapsis? In which stage it is observed?

Ans. The pairing of two homologous chromosomes during the zygotene substage of meiotic prophase I is known as synapsis. They are of two types, viz pro-terminal and pro-centric. In case of pro-terminal synapsis, the synapsis starts from the terminal end of homologous chromosomes and move towards the centre. In case of pro-centric synapsis, the synapsis starts from the centre and move towards the periphery.

It is observed in zygotene subphase of meiotic prophase.

5. State the importance of mitotic cell division.

Ans. Mitotic cell division has the following importance:

- (i) The process generates daughter cells with equal number of chromosomes and hence the chromosome number is maintained.
 - (ii) It prevents loss of cells and promotes growth.
- (iii) The same genetic features in the daughter cells are maintained like the parent cell.

- (iv) It maintains the balance between DNA and RNA.
- (v) It helps in the healing of wound.
- [6] What are the major events of metaphase?

Ans. The following changes take place during metaphase:

- (i) The nucleolus and nuclear membrane disappear.
- (ii) The chromosomes are arranged on the equatorial plane in such a way that their centromeres remain at the centre and their chromatids remain at the two sides.
 - (iii) The chromosomal fibres get attached to the kinetochore of chromosomes.
 - (iv) The continuous fibres run along the entire cell joining the two poles of the cell.

7. What are the major events of anaphase?

Ans. The various events of anaphase are as follows:

- (i) The chromosomal fibres gradually become small because of depolymerization.
- (ii) A repulsive force is generated from both side of the chromosome and as a result of which it divides longitudinally.
- (iii) The chromosome after the longitudinal division move towards the opposite poles.

8. Give a brief description of synapsis.

Ans. The process of synapsis occurs during the zygotene subphase of meiotic prophase I. During this phase, the homologous chromosomes come close to each other. They are separated by a $0.2~\mu$ broad band called synaptinemal complex having a central dark band and two peripheral light bands. This region separates the homologous chromosomes and prevents crossing over in between.

9. State the importance of interphase and describe the cell organelles during this stage. [J.E.E. 1989]

Ans. The importance of interphase are as follows:

- (i) In this phase, various anabolic processes take place within the cell and the cell prepares itself for division.
 - (ii) The different components needed for cell division are formed within the cell.
 - (iii) The centriole divides during this phase in animal cell.
 - (iv) In the S phase, DNA is divided and the chromosome gets thickened.
 - (v) RNA and protein synthesis starts from G, phase and continues till G, phase.
- (vi) In recent year, two check points have been denoted in the G₁ and G₂ substages, which help in the proper division of the cell.

The different organelles of the cell during this stage are as follows:

The nuclear membrane and nucleolus are intact. The DNA and RNA synthesis take place. The chromosomes are not distinct, the chromatin threads in certain areas become swollen at certain areas. The organelles like mitochondria, golgibody, plastids undergoes replication and becomes doubled. The centrioles of animal cell divides and move towards opposite poles and their astral protein fibres aggregate together to form spindle apparatus.

10. Where and when meiosis takes place in living organism? What is crossing over? What are its significance? [J.E.E. 1986]

Ans. Meiosis takes place in the germ cell of living organism. In plants it takes place during the formation of gametophyte from sporophyte. In animals it takes place in the gonads, during the formation of spermatozoa and ova.

The exchange of chromatid segments between non-sister chromatids of homologous chromosomes during the pachytene substage of meiotic prophase I is known as crossing over.

The significance of crossing over are as follows:

- (i) The chromosome shows structural variation by crossing over.
- (ii) It causes variation within gametes and there by brings about variation within individuals.
 - (ii) This variation paves the way of evolution.
 - 11. State the importance of divisional stages.

Ans. The stages of the cell cycle during when the parent cell produces its own replicate is known as divisional stages. It has very small duration in comparison to the interphase. The different divisional stages are prophase, metaphase, anaphase and telophase. The importance are:

- (i) One single cell produces many replicates.
- (ii) An organism moves into multicellular condition from unicellular condition.
- (iii) It helps in the growth of an organism and development of organs.
- (iv) The germ cell produced the gamates.
- (v) It results in healing of wounds.
- 12. State the importance of interphase.

Ans. The intermediate stage between two successive divisions is known as interphase. It is of tremendous importance and occupies more than $\frac{2}{3}$ rd of the cell cycle. It is divided into 3 substages, viz. G_1 , S and G_2 .

G₁ substage: It occupies 30-40% of the interphase. It helps in the synthesis of RNA and protein.

S substage: It is 30-50% of the interphase and helps in the replication of DNA and there by helps the chromosome to divide at a later stage.

 G_2 substage: It is comparatively short and important stage, occupying 10-20% of interphase. It helps in the synthesis of RNA, ribosome and spindle fibre proteins. The chromatin thickens and the nucleus increases in volume. The chromosomes differentiate from the chromatin material. The G_1 and G_2 substages have two check points, which help in the proper division of the cell.

13. Wht is zygotic, sporic and gametic meiosis?

Ans. In zygotic meiosis, the diploid zygote undergoes meiosis to produce haploid gametes. It is observed in green and other types of algae.

In sporic meiosis, the spore mother cell undergoes meiosis to produce the haploid spores and marks the beginning of gametophytic generation. It is found in bryophytes, pteridophytes and higher plants.

The gametic meiosis occurs in the germ cells of higher animals, helping in the production of gametes.

14. What are crossing over and chiasma? What is their order of occurrence?

Ans. Crossing over is a phenomenon of mutual exchange of non-sister chromatids of homologous chromosomes occurring during the pachytene substage of meiotic prophase I.

In the diplotene subphase of meiotic prophase I, the homologous pairs of chromosomes show repulsion between themselves and at the sometime they remain attached at the point of crossing over, which is called chiasma. As a result of chiasma formation, the chromosomes form X like configuration.

According to classical theory, chiasma occurs before crossing over, but according to chiasma type theory, crossing over is followed by chiasma formation.

15. What is the importance of crossing over? What is recombination?

Ans. (i) Crossing over results in the structural and functional change of chromosome.

(ii) It results in the variation within the gametes of an organism.

(iii) It causes variation within individuals i.e. no two individuals look the same.

(iv) It results in the mixing of genes, which pave the pathway for evolution and origin of new species.

As a result of crossing over the chromatids from different chromosomes unite and as a result of which new sequence of genes are produced and is referred to as recombination.

16. Name the scientists who discovered the following components of cell: Chromosome, polytene chromosome, lamp brush chromosome, nucleosome, cell cycle, synaptinemal complex.

Ans. Chromosome: Waldeyer—1888.
Polytene chromosome: Balbiani—1881.
Lampbrush chromosome: Ruckert—1891,

Nucleosome: Comberg—1974.
Cell cycle: Howard and Pele—1953.
Synaptinemal complex: Moses—1956.

17. Describe the major events of prophase.

Ans. (i) The nucleus become dehydrated and the chromosomes become distinct.

(ii) The chromatin fibres undergo replication.

(iii) The chromatids of chromosomes remain in divided state, but the centromeric region remain undivided.

(iv) The kinetochore proteins remain deposited in the centromeric region.

(v) The chromosomes become thickened.

(v1) The nucleolus gets attached to the nucleolus organization region of the chromosomes.

18. What are metakinesis and bipolar pressure?

Ans. The process by which the chromosomes move towards the equatorial plane is known as metakinesis. The bipolar pressure exists between the kinetochore and the microtubule of the spindle fibres, which help the chromosomes to remain at the equatorial plane.

Both metakinesis and bipolar pressure are observed in a single cell during the prometaphase the equatorial plane is known as **cryptomitosis**.

19. What are S.P.A., M.P.F. and M.D.F in relation to cell division?

Ans. S.P.A.—S-phase activator: it is a protein that helps in the DNA replication at S-phase.

M.P.F.—M-phase promoting factor: it is the cytoplasmic protein of metaphase stage that helps in the aggregation of chromosomes.

M.D.F.—M-phase delaying factor: it is a cytoplasmic protein formed in the S-phase that inhibits the activity of M.P.F., and thereby delays the process of metaphase.

20. What are contractile ring and stem body? Where are they present?

Ans. A contractile ring formed of microscopic fibres, that are distributed in the cytoplasm of certain animal cell like muscle cell and help in the process of cytokinesis.

Stem body is the contracted spindle fibres that contract gradually at the end of karyokinesis and occupy the equatorial plane during cytokinesis. It helps in the process of cytokinesis by invagination. They are both found in dividing animal cell.

21. Describe briefly the leptotene and zygotene substages of meiotic prophase I.

Ans. Leptotene: (i) The nucleus gradually becomes dehydrated.

- (ii) The chromosomes undergo progressive despiralization and gradually become elongated.
 - (iii) The chromatin remain in joined state forming synaptic knot and bouquet stage.
- (iv) The chromosomes remain in their early stage of formation with equidistant chromomeres.
 - (v) In case of animal cells, the centrioles divide and move towards opposite poles.

Zygotene: (i) The homologous chromosomes undergo pairing by synapsis forming bivalents.

- (ii) The homologous chromosomes are separated by an intermediate zone of $0.2~\mu$ thickness called synaptonemal complex.
 - (iii) Chromosomes undergo further thickening by condensation.
 - (iv) The nucleolus gets partially disorganized.
 - 22. What is crossing over? Give its brief description.

Ans. The process of exchange of chromatid segments between non-sister chromatids of homologous chromosomes during the pachytene subphase of meiotic prophase I is known as crossing over.

The various events of crossing over are as follows:

- (i) A gap is created in the coiled chromatid under the action of enzyme endonuclease.
- (ii) These gaps are usually at the same point of the non-sister chromatids of the two homologous chromosomes.
 - (iii) The chromatid segments are mutually exchanged between the two chromosomes.
 - (iv) The chromatid segments rejoin with the help of enzyme ligase.
 - 23. State the major events of diplotene and diakinesis.

Ans. Diplotene: (1) The homologous chromosomes exhibit de-synapsis.

- (ii) The chromosomes during this time remain attached by chiasma.
- (iii) The chiasma gradually moves towards the terminal end of chromatid by terminalization.
 - (iv) There may be some RNA synthesis noted at this phase.
 - (v) The chromosomes exhibit rotation at the point of chiasma.

Diakinesis: (i) The nucleolus gets degenerated.

- (ii) The bivalents become smaller in size.
- (iii) The terminalization and rotation continue.
- (iv) The nuclear membrane gets degenerated towards the end of diakinesis.
- 24. Describe the major events of first metaphase and anaphase of meiosis.

Ans. First metaphase: (i) The astral protein of centriole forms the spindle fibres.

- (ii) The bivalents are arranged on the equatorial plane in such a way that their chromatids remain on the equatorial plane and they are joined by the spindle fibres at the centromeric regions.
 - (iii) A force of repulsion develops between the pair of homologous chromosomes.

First anaphase: (1) The pair of homologous chromosomes divide and each individual chromosome moves towards the opposite pole.

- (ii) The spindle fibres (chromosomal fibres) are shortened by depolymerization.
- (iii) The chromosome number in the two poles are haploid (i.e. half of the diploid set).

(iv) Each chromosome has one non-cross over chromatid and one cross-over chromatid (modified due to crossing over).

25. Describe briefly the events of second metaphase and anaphase of meiosis.

Ans. Metaphase II: (i) The chromosomes are arranged on the equatorial plane like mitosis.

(ii) The centromeres remain on the equatorial plane.

(iii) The tactic fibres are attached to the centromeres of chromosomes.

Anophase II: (i) The chromosomes are arranged uniformly on the equatorial line.

(ii) The chromosomes divide longitudinally due to the shortening of the tactic fibres.

(iii) The chromosomes move towards the opppsite poles after division.

• [B] Distinguish between:

1. Distinguish between Crossing over and Translocation.

Crossing over	Translocation
(i) It occurs between homologous chromosomes. (ii) It occurs during the pachytene substage of meiotic prophase I. (iii) The chromosomes remain in tetrad condition. (iv) It causes variation of gametes. (v) It is a normal process, not harmful to the organism.	(i) It occurs between non-homologous chromosomes. (ii) It occurs during interphase. (iii) The chromosomes are in diad condition. (iv) It causes variation in the somatic chromosomes. (v) It is an abnormal process, which may be harmful to the organism.

2. Distinguish between Mitosis and Meiosis.

Ans.			
Mitosis	Meiosis		
(i) It occurs in vegetative cell. (ii) It produces two daughter cells. (iii) The chromosome number remains the same in the mother and the daughter cells.	(i) It occurs in germ cell. (ii) It produces four daughter cells. (iii) The chromosome number is reduced to half in the daughter cells.		
(iv) The chromosomes do not show any modification. (v) The cell divides only once. (vi) There is a single moderate prophase.	(iv) The chromosomes are modified due to crossing over. (v) The cell divides twice. (vi) There are two prophases, the first one is very long and complicated, having five subphases.		
(vii) The interphase is present, but there is no interkinesis. (viii) The process maintains the chromosome number in the vegetative cell.	(vii) The interphase and interkinesis, both are present. (viii) The chromosome number are reduced from diploid to haploid in the gametes and there by the chromosome		

number is maintained through successive

generations.

3. Distinguish between Interphase and Interkinesis.

Ans.

Interphase	Interkinesis
(i) It is the intermediate phase between two successive divisions. (ii) It is very long with three subphases of G ₁ , S and G ₂ .	(i) It is the intermediate phase between first and second meiotic divisions. (ii) It is shorter without any subphase.
(iii) It involves synthesis of DNA, RNA and protein. (iv) It is not the true resting phase.	(iii) It does not involve DNA, RNA and protein synthesis. (iv) It is the true resting phase.

(ii) It is very long with three stiophases of G_1 , S and G_2 . (iii) It involves synthesis of DNA, RNA and protein. (iv) It is not the true resting phase. 4. Distinguish between mitosis in pla	(iii) It does not involve DNA, RNA and protein synthesis. (iv) It is the true resting phase.
Ans.	
Plant cell mitosis	Animal cell mitosis
(i) In this case, the spindle fibres are formed from nucleoplasmic protein. (ii) There is no role of centriole in cell division. (iii) There is no distinct method of chromosome arrangement in the equatorial plane. (iv) The middle lamella, primary wall and secondary wall are formed at the end of cytokinesis.	(i) The spindle fibres are formed from astral protein of centriole. (ii) Centrioles are involved in spindle formation. (iii) The longer chromosomes are arranged in the outer portion of the equatorial plane, while the smaller chromosomes are arranged in the interior portion of the equatorial plane. (iv) The middle lamella, primary wall and secondary wall are not formed.
(v) The equatorial plane does not show the formation of any type of	(v) The equatorial plane shows the formation of two lateral constrictions,
constriction.	which gradually more inwards.
(vi) The stem body and contractile rings are not formed.	(vi) Stem body and contractile rings
(vii) The cells do not separate at the	(vii) The cells may separate at the end
end of cytokinesis.	of cytokinesis.

5. Distinguish between Cell plate and Stem body. Ans.

			Cell	plate	
(i)	It	is	observed	during	cytokinesis

- of plant cell.
- (ii) It is formed after the process of karyokinesis is completed.
- (iii) It is formed from the phragmoplast.
- (iv) It helps in the formation of middle lamella.

Stem body

- (i) It is observed during cytokinesis of animal cell.
- (ii) It is formed before the completion of karyokinesis.
- (iii) It is formed from the contractile spindle fibres.
- (iv) It helps in the formation of lateral constriction during cytokinesis in animal cell.

6. Distinguish between Primary metaphase and Secondary metaphase. Ans.

Primary metaphase	Secondary metaphase
(i) It represents the initial stage of	(i) It represents the last stage of
metaphase.	metaphase.
(ii) It is a relatively shorter phase.	(ii) It is a relatively longer phase.
(iii) The process of spindle fibre	(iii) The spindle fibres are divided into
formation continues during this stage.	chromosomal fibres and interzonal fibres.
(iv) The chromosomes are not always	(iv) The chromosomes are arranged
arranged uniformly along the equatorial	uniformly in the form of X like
plane.	configuration at the equatorial plane.
(v) It may show synthesis of RNA at	(v) There is no RNA synthesis during
the initial stages.	this stage

7. Distinguish between Amitosis and mitosis.

Amitosis

Ans.

(i) The nucleus divides directly in this	(i) The nucleus divides through
process.	various divisional stages.
(ii) This process does not lead to	(ii) The process leads to the separation
separation of chromosome and	of chromosome and chromatid.
chromatid.	
(iii) It does not form spindle fibres.	(iii) It forms spindle fibres.
(iv) The nuclear membrane may be	(iv) The nuclear membrane is present
absent, if present, it does not undergo	and disappears in the course of cell
degeneration.	division.
(v) It may produce two unequal cells.	(v) It produces two equal cells.
(vi) It is found in bacteria and yeast.	(vi) It is found in higher plants and
	animals.

8. Distinguish between Synapse and Synapsis.

[J.E.E. 1990]

Mitosis

chromosomes takes place by this process.

Ans.	napsis. [5.E.E. 177		
Synapse	Synapsis		
(i) The structural and functional	(i) The pairing of two homologous		
junction of two neurones are called	chromosomes is known as synapsis.		
synapse.			
(ii) It is formed due to the formation	(ii) It is formed by the pairing of two		
of a junction between the axon of one	homologous chromosomes.		
neurone and the dendron of another			
neurone.			
(iii) It is of 3 types, i.e. axo-dendronic,	(iii) It cannot be classified.		
axo-axonic and axo-somatic.			
(iv) The transmission of stimulus	(iv) The crossing over between non-		
takes place across the synapse.	sister chromatids of homologous		

9. Distinguish between Karyokinesis and Cytokinesis.

[J.E.E. 2001]

Ans.

telophase.

Karyokinesis	Cytokinesis
(i) The nuclear division of a cell is called karyokinesis. (ii) By this process the parent nucleus divides into two daughter nucleus and the genetic material is transferred to the next	(i) The cytoplasmic division of a cell is called cytokinesis. (ii) This process divides the entire cell and the cell organelles are divided into the two daughter cells.
generation. (iii) The process of karyokinesis occurs before cytokinesis. (iv) This process has 4 major stages, viz. prophase, metaphase, anaphase and	(iii) Cytokinesis occurs after karyokinesis. (iv) The process does not have any sub-stages.

10. Distinguish between Chromomere and centromere. Ans.

Chromomere	Centromere
(i) They are rounded bodies formed by the coiling of chromonema around rounded core proteins. (ii) Chromomere are classified as centromeric chromomere and chromatid	(i) They are unstained region of metaphase chromosome, to which the chromatids are attached. (ii) They cannot be classified in that way.
chromomere. (iii) They are smaller in size and more in number. (iv) They are not attached to spindle fibres.	(iii) They are bigger in size and less in number. (iv) They are attached to spindle fibres.

• [C] Short answer type questions:

1. How many cells are produced in meiosis?

[J.E.E. 2001]

Ans. Four.

2. What is meiosis?

J.E.E. 19961

Ans. Meiosis is a special type of cell division, occurring in the germ cells by which the nucleus of the diploid mother cell divides twice to produce four haploid daughter nuclei.

3. Where does meiosis take place?

[J.E.E. 1996]

Ans. Meiosis takes place in the diploid reproductive mother cell of an organism.

4. Why is meiosis called reductional division?

[J.E.E. 1996, 2002]

Ans. Meiosis is also called reductional division because the diploid chromosome number of the mother cell is reduced to half i.e. haploid in the daughter cells.

5. What is the chromosome number of human spermatozoa? [J.E.E. 1996] Ans. 23 (22A + X or 22A + Y).

6. What are the different stages of cell cycle?

[J.E.E. 1995]

Ans. The different stages of cell cycle are G_1 , S, G_2 and M phase.

7. State the location of Go stage in cell cycle.

[J.E.E. 1995]

Ans. The G₀ state is actually the arrested G₁ stage of a cell that does not exhibit division.

8. What are amphiastral and anastral mitosis?

[J.E.E. 1995]

Ans. The process of mitosis in which the spindle fibres are formed from the astral rays of centriole is known as amphiastral mitosis, while that in which the nucleoplasmic protein forms the spindle is known as anastral mitosis. Amphiastral mitosis takes place in animal cell, while anastral mitosis takes place in plant cell.

9. In which stage of mitosis, the centromere is divided into two ?[J.E.E. 1995]

Ans. The centromere is divided into two during the anaphase of mitosis

10. Who discovered the following?

[J.E.E. 1994]

(a) Electron microscope. (b) One gene one enzyme theory.

Ans. (a) Electron microscope —Knoll and Ruska. (b) One gene one enzyme theory—Beadle and Tatum.

11. Which substage of meiosis exhibits chiasma formation? [J.E.E. 1992]

Ans. Chiasma formation takes place in the diplotene subphase of meiotic prophase I.

12. Where does meiosis takes place in flowing plants?

Ans. Meiosis takes place in the microspore mother cell of the anther and megaspore mother cell of the ovule of flowering plant.

13. Why mitosis is called equational division.

[J.E.E. 1990]

Ans. Mitosis is also called equational division because the daughter cells have same number of chromosomes as mother cell and bear the same characteristic feature as the mother cell.

14. What are the significances of mitosis?

[J.E.E. 1990]

Ans. (i) The chromosome number is maintained in the daughter cell as in the mother cell.

- (ii) It helps in the growth of an organism.
- (iii) It helps in the healing of wounds.

15. What is heterotypic cell division?

[J.E.E. 1987]

Ans. The first meiotic division is called heterotypic division because the chromosome number is reduced to half and thereby a diploid cell produces two haploid cells.

16. Which cell division is devoid of G₂ subphase?

Ans. In case of mammalian spermatozoa production there is G_2 phase observed during the divisional stages. There is also no G_1 and G_2 phases observed during the cleavage of the embryo.

17. What is the nature of division in amitosis?

Ans. In case of amitosis, there is no spindle formed the cell divides by simultaneous appearance of constriction at the nucleas and the equatorial region of the cell. Hence the division is called direct cell division.

18. Which types of cells do not exhibit mitosis?

Ans. In case of higher animals, the matured RBC, the matured germ cell and the neurone do not exhibit mitosis. In case of plants, apart from the dead elements like trachea, xylem fibres, phloem fibres, the sieve tubes, inspite of being a living tissue, do not exhibit mitosis because the nucleus is absent.

19. Why mitosis does not take place in matured neurone of higher animals?

Ans. The matured neurone of higher organisms are devoid of functional centrioles. so the spindle fibres are not formed and the cells are unable to divide.

20. What is metakinesis?

Ans. The process by which the chromosomes distributed in the entire cytoplasm move towards the equatorial plane just before metaphase is known as metakinesis.

21. What is meant by pericentriolar cloud?

Ans. In case of the division of eukaryotic animal cell, the microtubules aggregate around the centriole at the opposite poles of the cell, which is referred to as pericentriolar cloud.

22. Name some components that prevent cell division.

Ans. Different antibiotics like chloramphenicol, tetracycline etc. prevent cell division of higher organisms.

23. Name the component that induces doubling of chromosomes.

Ans. The application of an alkaloid colchicine obtained from a liliaceae plant Colchicum automnale induces doubling of chromosomes during polyploidy.

24. What is interkinesis?

Ans. The short intermediate resting phase between the first and second meiotic division is known as interkinesis.

25. What is synapsis?

Ans. The pairing of homologous chromosomes or formation of bivalents during the zygotene substage of meiotic prophase I is known as synapsis.

26. What is the name given to the intermediate region of bivalents?

Ans. The intermediate region between the chromosomes of a bivalent is known as synaptonemal complex.

27. What is the major component of spindle fibre?

Ans. The major component of spindle fibre is tubulin protein joined by disulphide linkage.

28. What is terminalization?

Ans. The movement of chiasma towards the terminal ends of chromatid in the diplotene substage of meiotic prophase I is known as terminalization.

29. When do the nuclear membrane and nucleolus disappear for the first time in meiosis?

Ans. The nuclear membrane and nucleolus disappear during the diakinesis substage of meiotic prophase I.

30. State the portion of chromosome to which the spindle fibres are attached during the anaphase.

Ans. The spindle fibres are attached to the microtubular organization centre of the kinetochore of primary constriction of chromosomes,

31. What type of bond is present in spindle fibres?

Ans. The tubulin protein units of spindle fibres are bound by disulphide linkage.

32. What is prometaphase?

Ans. The short intermediate phase between prophase and metaphase is known as prometaphase.

33. What changes take place in the spindle fibres during anaphase?

Ans. The spindle fibres are shortened by depolymerisation and as a result the chromosomes are divided longitudinally.

34. In which divisional stage does the dominant and recessive alleles are separated?

[J.E.E. 2002]

Ans. The dominant and recessive alleles are separated during the first anaphase of meiosis.

35. Which organelle helps in the formation of astral spindle? [J.E.E. 2002] Ans. Centriole.

36. What is amitosis? Give scientific names of 2 organisms, where it is found.

Ans. Amitosis is a method of direct cell division by which the nucleus and cytoplasm divides directly without the formation of spindle fibres.

Example: Bacteria—Escherichia coh. Yeast—Saccharomyces cerevisiae.

37. What is Barr body?

Ans. The second X chromosome in human female becomes heterochromatinized and forms the dark stained body in the interphase nucleus, which is called Barr body after the name of its discoverer (M. Barr) and commonly used in determining sex in female.

38. Name two autosomal diseases.

Ans. The two autosomal diseases are:

(i) Down syndrome: Due to trisomy at 21st chromosome in man.

(ii) Cri-du-chat syndrome: Due to deletion of the long arm of 5th chromosome in man.

39. What is endomitosis?

[J.E.E. 1999]

Ans. The repeated division of the chromosome strands within the intact nuclear membrane is known as endomitosis. This gives rise to polytene chromosomes or salivary gland chromosomes.

40. What is the importance of interphase?

[J.E.E. 1998]

- Ans. (1) During interphase, the cell prepares itself for the next successive division.
- (ii) The chromosomes are thickened due to the synthesis of DNA, RNA and protein.
- (iii) Profuse amount of ATP is produced, which provides the energy during cell division.
 - (iv) In animal cell the centriole divides to mark the beginning of cell division.
- (v) The aggregation of microtubules take place, which will form the spindle fibres at a latter stage.
 - 41. Where does meiosis take place in pea plant and guineapig? [J.E.E. 1998]

Ans. Meiosis takes place within the anther and ovule of pea plant and in case of guineapig, it takes place in the testis and ovary.

42. What is the importance of meiosis?

J.E.E. 1992

- Ans. (i) Due to meiosis, the gametes are produced and chromosome numbers are reduced from diploid to haploid. Thus the chromosome number in a particular organism is maintained.
- (ii) Due to crossing over, the non-sister chromatid fragments of homologous chromosomes are exchanged, which creates variation within gametes and thereby paves the pathway for evolution.
 - 43. How are four cells produced from a single cell in meiosis? [J.E.E. 1991] Ans. Meiosis shows two successive divisions, which are called meiosis I and

meiosis II. During meiosis I, a single diploid cell produces 2 haploid cells. In

meiosis II, those two haploid cells produce 4 haploid daughter cells by equational division. Thus in meiosis, a single diploid cell produces 4 haploid daughter cells.

44. What is the importance of crossing over? [J.E.E. 1

Ans. (1) It leads to variation within genome and thus brings about speciation.

- (ii) It causes organic evolution.
- (iii) It denotes the position of a gene on a chromosome.
- (iv) It results in the production of variable gametes, as a result of which the progenies from the same parent vary from each other.

45. What is cell cycle?

Ans. The sequence of events denoting the various physiological activities in a cell is known as a cell cycle. There are four major stages in a cell cycle, the M phase (divisional phase), the G_1 (gap I phase), S phase (synthetic phase) and G_2 (gap II phase). The G_1 , S and G_2 phases are together called interphase.

46. What are nuclear and cytoplasmic spindle?

Ans. In case of plant cell, there is no centriole, so the spindle fibres are formed from nucleoplasmic protein and is called nuclear spindle. But in case of animal cell, the astral rays of the centriole forms the spindle and is called centriolar spindle.

47. In which particular stage of cell division does the nuclear membrane and nucleolus disappear and at which phase does it return back?

Ans. The nuclear membrane and nucleolus disappear at the end of prophase and it comes back at the end of telophase.

48. How are the nucleolus and nuclear membrane formed at the end of karyokinesis?

Ans. At the end of karyokinesis, the nuclear membrane is formed from the E. R. and the nucleolus organization region produces the r-RNA, which along with protein forms the nucleolus.

49. What are bivalents and tetrads?

Ans. In the zygotene subphase of meiotic prophase I, the homologus chromosomes come close to each other by the process of synapsis and is called bivalents. The chromatids of these chromosomes divide longitudinally except at the region of centromere and the four chromatids together are called tetrads.

50. What is recombination nodule?

Ans. In the pachytene subphase of meiotic prophase I, the synaptinemal complex shows the presence of two round bodies of 100 nm diameter on its both side called recombination nodule. Their number denotes the frequency of crossing over.

51. What are homologous chromosomes?

[J.E.E. 2002]

Ans. The homologous chromosomes are chromosomes of similar structure and shape that come close to each other by the process of synapsis during zygotene subphase of meiotic prophase I to form bivalents.

52. What is meant by Turner's syndrome?

Ans. The Turner's syndrome is an aneuploid with only one X chromosome (i.e. 45 chromosomes) without fully developed sex organs and are identified as intersex.

53. What is Klinefelter's syndrome?

Ans. It is caused by non-disjunction of the sex chromosomes during gamete formation and the individual has 47 chromosomes *i.e.* XXY configuration, The individuals are identified as males with feminine characters.

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54. What is Down syndrome?

Ans. It is caused by the trisomy of the 21st chromosome, so the individual has 47 chromosomes. They are characterized by mental retardation, half moon face, puffy cheeks, small eyes. Since the face is Mongolian type, the disease is called Mongolian idiocy.

• [D] Multiple choice type questions:

- 1. The example of direct cell division is
- (a) amitosis (b) mitosis (c) meiosis.
- 2. The process of amitosis occurs in
- (a) yeast (b) bacteria (c) both.
- 3. The structure that is not formed during amitosis are
- (a) spindle fibre (b) chromosome (c) phragmoplast.
- 4. Amitosis in bacteria is seen during
- (a) binary fission (b) multiple fission (c) fragmentation.
- 5. The other name for mitosis is
- (a) direct cell division (b) equational division (c) reduction division.
- 6. The structure formed from phragmoplast in plant cell is
- (a) middle lamella (b) primary wall (c) secondary wall.
- 7. The exact point of attachment of the spindle fibres on the chromosome is
- (a) MTOC (microtubule organization centre) (b) centromere (c) kinetochore.
- 8. The mitosis present is animal cell is
- (a) anastral (b) amphiastral in nature.
- 9. The process of endomitosis occurs in
- (a) m-chromosome (b) polytene chromosome (c) L chromosome.
- 10. The arrested interphase in certain animal cell is also called
- (a) G_0 stage (b) G_1 stage (c) G_2 stage.
- 11. The longest phase in a cell cycle is
- (a) prophase (b) metaphase (c) anaphase (d) interphase.
- 12. The nuclear membrane and nucleolus disappear during
- (a) prophase (b) metaphase (c) anaphase.
- 13. The chromosomes are arranged on the equatorial plane during
- (a) prophase (b) metaphase (c) anaphase.
- 14. The process of furrowing is observed during the cytokinesis of
- (a) plant cell (b) animal cell (c) both plant cell and animal cell.
- 15. The phragmoplast consists of
- (a) dictyosomes (b) desmin tubules (c) both.
- 16. The process which is not properly completed in cancerous cell is
- (a) karyokinesis (b) cytokinesis (c) interphase.
- 17. Mitosis results in
- (a) growth (b) healing of wound (c) differentiation (d) all the above.
- 18. Meiosis is also called
- (a) reduction division (b) equational division (c) direct cell division.
- 19. Meiosis occurs in the
- (a) spore mother cells (b) germ cells (c) both.

İs

- 20. The gene that causes destruction of a cell is called
- (a) operator gene (b) promoter gene (c) repressor gene (d) terminator gene.
- 21. The process of programmed cell death is also called
- (a) apomixis (b) endomixis (c) apoptosis.
- 22. The intermediate phase between meiotic divisions is also called
- (a) interphase (b) interkinesis (c) prometaphase (d) G, phase.
- 23. Synapsis occurs during
- (a) leptotene (b) zygotene (c) pachytene (d) diplotene.
- 24. Bouquet stage is the other name for
- (a) leptotene (b) zygotene (c) pachytene (d) diplotene.
- 25. Crossing over occurs during
- (a) leptotene (b) zygotene (c) pachytene (d) diplotene.
- 26. The last stage of meiotic prophase I is
- (a) pachytene (b) diplotene (c) diakinesis.
- 27. The structure that is separated during anaphasic separation of chromosome
- (a) bivalent (b) individual chromosome (c) chromatid (d) centromere
- 28. The region between two homologous chromosomes is called
- (a) synaptonemal complex (b) chromonemata (c) bivalent (d) chromomere.
- 29. The second division of meiosis is
- (a) equational division (b) reductional division (c) amitosis (d) direct cell division.
- 30. Meiosis occurs in plant in the
- (a) microspore mother cell (b) megaspore mother cell (c) both.
- 31. The phenomenon of crossing over leads to
- (a) variation (b) adaptation (c) mutation.
- 32. The cancer of connective tissue is called
- (a) carcinoma (b) sarcoma (c) myeloma (d) melanoma.

Answers to Q. D

[1] amitosis; [2] both; [3] spindle fibre; [4] binary fission; [5] direct cell division; [6] middle lamella; [7] MTOC (microtubule organization centre); [8] amphiastral in nature; [9] polytene chromosome; [10] G₀ stage; [11] Interphase; [12] metaphase; [14] animal cell; [15] both; [16] karyokinesis; [17] all the above; [18] reduction division; [19] both; [20] terminator gene; [21] apoptosis; [22] interkinesis; [23] zygotene; [24] leptotene; [25] pachytene; [26] diakinesis; [27] bivalents; [28] synaptonemal complex; [29] equational division; [30] both; [31] variation; [32] sarcoma.

Chapter 7: Genetics

• [A] Long answer type questions:

1. How did Mendel control the percentage of his experimental Garden pea (Pisum sativum) plants?

Ans. The flower of a garden pea plant contains both male and female sex organs, *i.e.* the flower is bisexual. The male organ is *stamen* which contains anther and filament. Anther produces the pollen, which contains the sperm nuclei. Under natural conditions, the pollen either moves from the stamen (male) to the stigma (the female part) of the same flower or is transferred by an insect (bee) to the stigma of another flower on another plant. The *pistil* (female organ) produces the egg in the ovary which is fertilized by pollen and subsequently the fertilized egg develops into a seed.

The petals of a garden pea flower are folded over the stamen and pistil in such a way that the majority insects are unable to enter the flower. Hence generally self-fertilization occurs in pea plant *i.e.* the egg of a flower is fertilized by pollen from the same flower. Subsequently, seeds of a self-fertilized pea plant develop into normal adults.

Mendel allowed self-fertilization in pea plant in some of his experiments, such as in development of pure strains and also in F₁ generation. For this, he covered the flowers by bags so that no insect can enter into the flowers and deposit pollen from another plant. When Mendel wanted cross-fertilization between the two parents of two pure strains, he removed the stamens of an inumature flower of one plant which behaved as a female flower and also removed the pistil of another immature flower of another plant to make it a male flower. Both the flowers were covered by bags. After maturation of flowers, Mendel transferred the pollen from male flower to the stigma of female flower for cross-fertilization.

Mendel thus controlled the percentage of his experimental garden pea plant (Pisum sativum) by controlling the flow of pollen to the eggs.

2. Under what conditions does Mendel's law of segregation apply?

Ans. Law of segregation as deduced by Mendel in his experimental material states the following ideas—

- (a) For each inherited trait in an organism there is a pair of discrete factors which are subsequently known as genes.
- (b) The pair of factors (genes) gets segregated during the formation of gametes; each gamete contains half of the factors, *i.e.* gametes are haploid in nature. Thus the fertilized egg has a pair of factors—one from each parental gamete.

(c) When the factors of a pair are different, one is dominant and the other is recessive. The dominant factor is fully expressed and the recessive factor remains unexpressed.

Mendel's most important contribution to biology is the law of segregation; because this law introduced the concept of hereditary factors which are discrete and have physical entities. These are not being blended when present together in the same organism. Mendel disproved the blending theory of inheritance by showing that although alleles of a trait disappears in the F_1 generation but reappears in the F_2 generation.

The law of segregation applies only to the organisms which reproduce sexually. In the sexual reproduction, diploid organisms produce haploid gametes. Moreover, the law of segregation applies only to traits which are controlled exclusively by a single pair of genes. Out of the single gene pair, one allele is dominant and the other allele is recessive. The law of segregation therefore does not apply in the following cases:

- (a) alleles that are incompletely dominant.
- (b) genes that collaborate or vary in their expression.
- (c) genes that are pleiotropic, i.e. where each gene having two or more phenotypic effects.
- (d) genes that are complementary or influenced by epistasis, *i.e.* effect of one gene is suppressed by another.
 - (e) one trait is expressed by many gene pairs.

In fact, very few traits are controlled exclusively by a single gene pair. Hence the law of segregation is not applicable in all cases of inherited traits.

3. What are the limitations of Mendel's Law of Independent Assortment?

Ans. Law of Independent Assortment as deduced by Mendel in his experimental material, pea plant states that the one pair of factors now known as genes segregate or assort independently during gamete formation. Thus one pair of factors or genes have no influence over another pair of factors (genes).

As for example, if the two pairs of factors were Yy and Rr, then during gamete formation, they are reduced to half. Y factor received a copy of R or r t e., they would have no influence over the other. As a result, four kinds of gametes, such as YR, Yr, yR and yr would be formed in equal frequency.

Law of independent assortment applies only to those gene pairs that lie on different pairs of homologous chromosomes. Thus one gene pair is located on one pair of homologous chromosomes and the other gene pair is located on another pair of homologous chromosomes. Mendel himself did not know about chromosomes. But he was lucky enough that all the traits he studied on garden pea were on different pairs of homologous chromosomes. That is why he concluded that the gene pairs segregate or assort independently of one another.

If the gene pairs of the traits, which were taken up by Mendel in his experimental process, were located on the same pair of homologous chromosomes, he would have found that the one gene pair had an influence over the another gene pair during the gamete formation. The genes on the same chromosome are usually linked and moved enblock during gamete formation except in crossing over. Hence, if gene Y would have been situated next to R on the same chromosome and gene y situated next to r on the other chromosome of the homologous pair, then they would have segregated enblock during the gamete formation provided there would have been no crossing overs. As a result of complete linkage, only two kinds of gametes would have been formed, such as one type Y and R, the other type y and r, Thus the law of independent assortment is applicable only on limited cases due to these limitations.

4. What are the advantages of using Drosophila (fruit fly) in genetic experiments?

Ans. There are many advantages of using fruit fly (Drosophila) in genetic experiments because of the following reasons:

- (i) Fruit fly is a tiny insect of about 2 mm size. In laboratory, it can be easily reared in small bottles with culture medium which is prepared by a mixture of sooji, molasses, active dried yeast and solidified with agar.
 - (ii) Fruit flies reproduce rapidly and a fertilized female fly lays about 100 eggs at a

time in the food material where the larvae hatch, feed on the culture medium and then pupate. After pupation, adult is formed within just 12 days. Hence the life cycle of fruit fly is very short and fruit flies can be bred throughout the year. Thus many generations are obtained in a year.

- (iii) Fruit fly shows a number of externally visible contrasting traits.
- (iv) Male and female fruit flies can be differentiated, so they can be interbred with desired genotypes.
- (v) Each cell of fruit fly has only four pairs of chromosomes which differ in size and are easily distinguishable. The 3 pairs of chromosomes are autosomes and one pair is sex chromosome. The sex chromosome pair in female is XX and in male is XY. The Y chromosome of male is J shaped. Thus it is relatively easy to establish gene linkages in chromosome pairs.
- (vi) Moreover, the giant chromosome of salivary gland cells of fruit fly facilitates gene mapping, since their banding patterns and the positions of chromosomal puffs are easy to be observed under a light microscope.
 - (vii) To study multiple alleles, Drosophila is ideal material.
- (viii) Geneticists are also trying for unraveling the relation between genes and behavior. In this respect, the behaviors of fruit flies provide the ideal material to geneticists.

• [B] Distinguish between:

1. Distinguish between dominant and recessive genes.

Ans.

Dominant Gene	Recessive Gene
(i) A gene which is able to express itself even in the presence of its contrasting recessive allele is known as	(i) A gene which is unable to express itself in the presence of its contrasting dominant allele is known as recessive
dominant gene. (ii) Dominant gene forms an active enzyme for expressing its effect.	gene. (ii) Recessive gene forms an incomplete enzyme which fails to express its effect.

2. Distinguish between Homozygous individual and Heterozygous individual. Ans.

Homozygous Individual	Heterozygous Individual
(i) An individual organism in which both the alleles of a trait are alike is known as homozygous individual. (ii) After meiosis, it produces only one type of gametes for the specific trait.	(i) An individual organism in which both the alleles of a trait are contrasting is know as heterozygous individual. (ii) After meiosis, it produces two different types of gametes for the specific trait.
(iii) It is genetically pure for the specific trait, hence breeds true. It produces offsprings with parental type of traits on self-breeding.	(iii) It is genetically hybrid <i>i.e.</i> not pure for the specific trait, hence it does not breed true. It produces offsprings with different types of genotypes on self-breeding.

3. Distinguish between Genotype and Phenotype. Ans.

Genotype	Phenotype
(i) Genetic constitution of an organism is known as genotype.	(i) Characteristics of an organism that are observed externally, constitute its phenotype.
(ii) Genetic constitution remains the same throughout the life of an onganism. (iii) Similar genotypic invdividuals develop similar phenotypic character in the same environment.	(ii) Characteristics of an organism may change with age and environment. (iii) Similar phenotypic individuals may or may not develop similar genotype.

(ii) Genetic constitution remains the same throughout the life of an onganism. (iii) Similar genotypic involviduals develop similar phenotypic character in the same environment.	may change with age and environment. (iii) Similar phenotypic individuals may or may not develop similar genotype.
4. Distinguish between Dominance and Incomplete dominance. Ans.	
Dominance	Incomplete Dominance
 (i) In a cross of two homozygous parents, the individuals of first filial generation (F₁) show character of one of the two homozygous parents. (ii) In the F₁ hybrid individuals, out of the two alleles only one allele is expressed. (iii) In case of dominance, phenotypic and genotypic ratios in F₂ are different. The phenotypic ratio is 3: 1 and genotypic ratio is 1:2:1. 	(i) In a cross of two homozygous parents, the individuals of first filial generation (F ₁) show intermediate character of the two homozygous parents. (ii) In the F ₁ hybrid individuals, both the alleles are present, but none of them are dominant; so they exhibit an intermediate phenotypic character parental types reappear in F ₂ generation. (iii) In case of incomplete dominance, the phenotypic and genotypic ratios in F ₂ are same, such as 1:2:1.
5. Distinguish between Dominance and Epistasis.	

Ans.	
Dominance	Epistasis
(i) In case of dominance, when two alleles of a trait are present in an organism, one of them is expressed and the other is suppressed in F, generation.	(i) In epistasis, it is the interaction between non-allelic genes, where a gene suppresses or modifies the phenotypic expression of a non allelic gene, i.e. inter-
i.e. intra-allelic interaction	allelic interaction

- (ii) Here one of the alleles of a trait suppresses the expression of the other allele of a gene pair.
- (iii) In case of dominance, both the alleles of a gene cannot be dominant at the same time.
- (ii) Here the alleles of a gene pair suppress the expression of another nonallelic gene pair.
- (iii) In case of epistasis, the two nonallelic genes can be mutually epistatic.

6. Distinguish between Test cross and Back cross.

Ans.

Test Cross	Back Cross
(i) It is a cross in which an individual	(i) It is a cross which is made between
with an unknown dominant phenotype is	F ₁ progeny and one of its parents.
crossed with a homozygous recessive	
parent for that trait.	
(ii) The genotype of an offspring can	(ii) Plant breeders make such crosses
be determined by test cross as done by	to improve the variety of crop plants.
Mendel in his experiments.	

7. Distinguish between Complementary gene and Supplementary gene. Ans.

Ans.	
Complementary Gene	Supplementary Gene
(i) Complementary genes are non-	(i) Supplementary genes are also non-
allelic dominant genes and each pair of	allelic dominant genes.
alleles are located in the separate pairs	
of homologous chromosomes.	
(ii) Both the genes act independently	(ii) Both the genes act independently
to express similar phenotypic trait.	to express a different type of phenotypic
	character.
(iii) The interaction of both genes	(iii) The interaction of both genes
produces a new trait.	produces their own effects independently
	and modify the expression.
(iv) In the F, progeny, ratio becomes	(iv) In F ₂ generation, ratio becomes
9:7.	9:3:4.

8. Distinguish between Monogenic Inheritance and Multiple gene inheritance. Ans.

Monogenic Inheritance

- (i) It deals with the discontinuous variations, *i.e.* no intermediate forms; hence they are known as qualitative traits.
- (ii) It is controlled by a pair of contrasting alleles (genes).
- (iii) Monogenic inheritance produces two distinct type of phenotypic characters and hence show discontinuous variation.
- (iv) In monogenic inheritance, a single dominant allele expresses the complete character.
- (v) F_1 progeny shows the dominant character of the parent.
- (vi) In monogenic inheritance, phenotype is not influenced by the environment.

Multiple Gene (Polygenic) Inheritance

- (i) It deals with continuous variations, *i.e.* intermediate forms are present; hence they are known as quantitative traits.
- (ii) It is controlled by two or more pairs of non-allelic genes.
- (iii) Polygenic inheritance produces wide range of phenotypic characters, hence shows continuous variation.
- (iv) In polygenic inheritance, a single dominant allele expresses only a part of the character.
- (v) F₁ progeny shows the intermediate character between the parents.
- (vi) In polygenic inheritance, phenotype is influenced by the environment.

• [C] Short answer type questions:

1. Who and when rediscovered Mendel's laws of heredity?

Ans. Mendelism was rediscovered by Hugo de Vries of Holland,

Eric Von Tschermak of Austria and

Karl Correns of Germany. It was rediscovered in 1900 A.D.

2. Name any three of the seven contrasting traits noted by Mendel in Garden pea. (Pisum sativum)

Ans. (i) Tall × Dwarf plant

(ii) Round seed × Wrinkled seed.

(iii) Yellow cotyledon × Green cotyledon.

3. What do letters P, F, F, and F, represent in heredity?

Ans. P = Parental generation.

F. = First filial generation.

 F_2 = Second filial generation

F_i = Third filial generation.

4. Mention Mendel's monohybrid and dihybrid ratios in \mathbf{F}_2 phenotypes and genotypes of monohybrid \mathbf{F}_2 .

Ans. (i) Monohybrid phenotypic ratio = 3:1

- (ii) Monohybrid genotypic ratio = 1:2:1 (iii) Dihybrid phenotypic ratio = 9:3:3:1
- 5. What law of heredity was derived by Mendel from a cross showing 3: 1 ratio in the F, phenotypes?

Ans. 'Law of segregation' was derived from Monohybrid cross.

6. What law of heredity was derived by Mendel from a cross showing 9:3:3:1 ratio in the F, phenotypes?

Ans. 'Law of independent assortment' was derived from Dihybrid cross.

7. What is pleiotropism? Cite an example.

Ans. In an organism, when a single gene is influencing the expression of two or more visible characters, it is called pleiotropy and this phenomenon is regarded as pleiotropism.

Example: Pleiotropic gene of Drosophila, such as the gene determining wing pattern.

8. What is genome?

Ans. Genome is defined as a complete set of chromosomes in which the genes are presented singly as in gamete. Gamete is in a state of haploid condition which is regarded as single genome.

9. What do you mean by gene pool?

Ans. All the genes present in an interbreeding population are together known as gene pool.

10. What is pedigree analysis? Give the significance of pedigree analysis?

Ans. Pedigree analysis is defined as the analysis of record of inheritance of a particular trait over two or more generations in a family tree.

Significance: This pedigree analysis helps in finding out the possibilities of inheritance of a trait in homozygous or heterozygous condition in a particular offspring.

11. Why Archibald Garrod is regarded as 'Father of Human Genetics'?

Ans. The study of inheritance of traits in human being is known as human genetics. The first study in human geneties was done by Archibald Garrod, an English Doctor in 1909. He discovered a human disease *Alkaptonuria* (black urine) which is caused by a recessive gene; the alkaptonuria disease is transmitted like a Mendelian factor. This

inborn error of metabolism was first studied by him. Hence, Archibald Garrod is regarded as father of human genetics.

12. What do you mean by identical and fraternal twins?

Ans. Identical twins are developed from a single zygote; hence they are also known as monozygotic twins. After the first cleavage, the zygote forms two blastomeres, which are separated and each of them subsequently forms a baby. Therefore, they have similar genetic constitution and they are of same sex. The characters that are similar in the identical twins are considered hereditary.

Fraternal twins are developed from two separate zygotes. Hence they are also known as dizygotic twins. Therefore, these two babies are no more alike and they may not be of the same sex. They are just like other children born at different times to the same parents.

13. Mention an important disease in man which is caused by autosomal disorder. How the disorder develops?

Ans. This disease is known as 'Down syndrome'. Down syndrome was first reported by Longdon Down in 1866. This disease is also known as Mongolism or Mongoloid idiocy.

This disease is developed due to *trisomy of 21st. chromosome i.e.* additional chromosome, as a result total chromosome number becomes 47 instead of 46. Trisomy develops due to *non-disjunction* of 21st. chromosome during oogenesis. Thus the ovum consists of 24 chromosomes. If such ovum is fertilized by a normal spermatozoon, the 21st. chromosome becomes trisomic and the zygote contains 47 chromosome. This trisomy causes the above mentioned disorder in man.

14. Explain how a XXY individual can arise in human being?

Ans. Abnormal types of eggs or sperms are developed during oogenesis or spermatogenesis due to non-disjunction (non-separation) of sex chromosome. Abnormal types of eggs are XX and O, abnormal types of sperms are XY and O (absence of X or Y means O). If an abnormal ovum is fertilized by a normal sperm, genetic imbalance will occur and as a result, genetic disorders will be produced in human being. Thus XXY male individual arise, when abnormal ovum containing XX sex chromosomes is fertilized by a normal sperm containing Y sex chromosome. This genetic disorder is known as *Klinefelter syndrome*, which causes mental retardation and often sterile individual,

15. What is chromosomal mutation? How it can be induced?

Ans. A change in the structure or number of chromosomes is known as chromosomal mutation.

It can be induced artificially by certain external factors. These external factors are called *mutagens* or mutagenic agents, such as *radiations* (X-rays, gamma rays, ultraviolet rays etc.), *chemicals* (formaldehyde, nitrous acid *etc.*) and *temperature*.

16. Mention the importance of mutations.

Ans. Mutations have many types of importance. These are mentioned below:

- (i) Mutations are of great importance in the production of new and useful varieties of plants, which are economically important.
- (ii) Mutations are also important in the development of useful races of domestic animals.
- (iii) Mutations are providing the variability within organisms in order to adapt to the changing environment .
 - (iv) Mutations are also important as raw materials for evolution.

17. Differentiate between:

- (a) Point mutation and Genomatic mutation.
- (b) Transition and Transversion.
- (c) Deletion and Translocation.

(d) Aneuploidy and Euploidy.

Ans. (a) Point mutation—It is a change in the structure of a gene which occurs at the time of DNA replication. Hence point mutation is also known as a gene mutation.

Genomatic mutation—It involves a change in the number of chromosomes.

(b) Transition—It is the replacement of a nitrogen base of DNA by another nitrogen base of its type (a purine, adenine replaced by another purine, guanine).

Transversion—It is the replacement of a purine base by a pyrimidine base, and vice versa, such as AT by TA (i.e. Adenine and Thymine by Thymine and Adenine)

(c) Deletion—A portion of a chromosome is separated and subsequently it is lost. The affected chromosome loses certain genes; as a result the chromosome becomes shorter.

Translocation—There is a breakage of a chromosome and the broken portion joins a non-homologous chromosome. Both the affected chromosomes are modified. One chromosome suffers deletion and becomes shorter than normal. The other gets an extra set of genes, as a result it becomes longer than the normal.

(d) Aneuploidy—It is the condition in which an organism has fewer or extra chromosomes than the normal diploid number of chromosomes. Aneuploidy commonly occurs due to non-disjunction of homologous chromosomes during formation of gametes.

Euploidy—It is the condition in which an organism has more than two sets of chromosomes. This condition occurs in nature due to the failure of chromosomes to separate during formation of gametes. It can be artificially induced by application of chemicals, such as colchicine.

18. What is Karyotype? How is it useful for human being?

Ans. Karyotype is the photographic representation of all chromosomes of a somatic diploid cell at mitotic metaphase stage. These metaphasic chomosomes of an organism are arranged in homologous pairs in the descending order of their size.

In a human Karyotype, the individual chromosome pairs are differentiated by their banding pattern by dyes, such as geimsa. Thus each chromosome of the 22 pairs of autosomes and sex chromosomes are identified. Hence the defect in any chromosome or numerical anomalies of chromosomes can be detected.

19. What is non-disjunction?

Ans. Non-disjunction may be defined as failure of the two chromosomes of a particular homologous pair to separate at the time of meiosis.

• [D] Multiple choice type questions :

- 1. Lamack and Darwin both of them believed in the idea that particles from all parts of the body come together to form egg and semen. This theory is called—
- (a) Spontaneous generation.(b) Mendelian inheritance. (c) Pangenesis.(d) Sexual inheritance.
- 2. Biologists first understood that both parents contribute to the characteristics of offspring in the—
 - (a) 15th century. (b) 12th century. (c) early 1900s. (d) early 1800s.
 - 3. Mendel published his experimental results in-
 - (a) 1866. (b) 1773. (c) 1568. (d) 1900.

4. Gregor Johann Mendel stated his experiments with pure strains of garden peas (Pisum sativum). A pure strain of garden peas was developed by removing all—

(a) male plants. (b) female plants. (c) weak plants. (d) atypical plants in each

generation.

5. The offsping of matings between two pure strains are known as-

(a) mutants. (b) hybrids. (c) P generation. (d) F₂ generation.

- 6. A single recessive trait which can express its effect should occur on-
- (a) any chromosome. (b) X-chromosome of male. (c) any autosome (d) X-chromosome of female.
- 7. A haemophilic man marries a normal homozygous woman. What is the probability that daughter will be haemophilic?

(a) 100% (b) 75% (c) 50% (d) 0%

- 8. Different mutations referrable to the same locus of a chromosome give rise to—
 - (a) Polygenes. (b) Multiple alleles. (c) Pseudo-alleles. (d) Oncogenes.

9. A colour blind person cannot distinguish-

(a) Red and green (b) Red (c) All colours (d) Green.

10. Crossing over in diploid organism is responsible for-

- (a) Linkage between genes (b) Segregation of alleles (c) Dominance of genes (d) Reombination of linked genes.
- 11. A human male has one Barr body in his somatic cell nucleus. The chromosome constitution must be—

(a) XYY (b) XO (c) XXY (d) XXXY.

- 12. A syndrome in which human has an extra X-chromosome is-
- (a) Klinefelter's syndrome.(b) Beeder's syndrome.(c) Down's syndrome.(d) Turner's syndrome.

13. Which one is a sex linked disorder?

- (a) Cancer, (b) Night blindness, (c) Colour blindness, (d) Leukemia.
- 14. The total number of chromosomes in the zygote of man is-

(a) 23, (b) 46, (c) 44, (d) 22.

- 15. The striking example of point mutation is found in a disease known as-
- (a) thalassemia, (b) sickle cell anemia, (c) Down's syndrome, (d) night blindness.

16. Recessive characters are expressed—

- (a) on any autosome, (b) on both the chromosomes of female, (c) only when they are present on X-chromosome of male. (d) only when they are present on X-chromosome of female.
 - 17. The functional unit of mutation is-

(a) muton, (b) recon, (c) gene, (d) cistron.

18. A Drosophila (Fruitfly) showing both male and female character is-

(a) Gynandromorph, (b) Heterozygous, (c) Gynander, (d) Hemizygous.

- 19. Number of chromosomes can increase or decrease due to-
- (a) Genetic repetition, (b) Mutation, (c) Non-disjunction, (d) All of these.

20. Genome is represented by-

- (a) Complete set of chromosomes, (b) All the genes present in the population, (c) Diploid set of chromosomes, (d) Haploid set of chromosomes.
- 21. The phenomenon of exchange of segments between paternal and maternal chromosomes is known as—
 - (a) Recombination, (b) Segregation, (c) Crossing over, (d) Linkage.

- 22. The substance that causes a definite change in genes is called-
- (a) Toxin, (b) Mutagen, (c) Cytotoxin, (d) Alkaloid.
- 23. Genes located on Y-chromosome are known as -
- (a) Holandric genes, (b) Mutant genes (c) Autosomal genes, (d) Sex-linked genes.
- 24. The idea that genes control the production of enzymes was given by-
- (a) R. D. Kornberg, (b) T. H. Morgan, (c) A. E. Garrod, (d) E. L. Tatum.

25. One gene one enzyme hypothesis was given by -

- (a) Johnson, (b) Jacob and Monad, (c) Beadle and Tatum, (d) Griffith.
- 26. The process of transfer of genetic information from DNA to RNA is-
- (a) Transcription, (b) Transversion, (c) Translocation, (d) Translation.
- 27. Initiation codon of protein synthesis in eukaryotes is-
- (a) GCA, (b) AUG, (c) GUA, (d) CCA.

28. The process of translation is-

- (a) DNA synthesis, (b) Ribosome synthesis, (c) RNA synthesis, (d) Protein synthesis.
- 29. Who proved that DNA is the basic genetic material?
- (a) Watson, (b) Griffith, (c) Harshey and Chase, (d) Boveri and Sutton.

30. In an animal cell, protein synthesis takes place-

(a) in the nucleus as well as in the cytoplasm, (b) in the cytoplasm as well as in the mitochondria, (c) only in the cytoplasm, (d) only on ribosomes attached to the nuclear envelope.

31. The genetic basis of haemophilia was revealed by studies of-

- (a) chromosomes in gametes, (b) family pedigrees, (c) prenatal gene products, (d) DNA sequences.
- 32. When two or more non-allelic gene pairs affect the same character, this is known as—
 - (a) pleiotropy, (b) total penetrance, (c) additive expressivity, (d) polygenic inheritance.
- 33. An interaction between non-allelic genes in which an allele at one locus prevents expression of an allele at another locus is called—
 - (a) complementation, (b) modification, (c) epistasis (d) collaboration.
- 34. When two non-allelic gene pairs influencing the same character interact to produce a novel phenotype, which neither gene pair could produce by itself, is known as—
 - (a) complementation, (b) collaboration, (c) modification, (d) epistasis.
 - 35. How many possible phenotypes are there for the ABO blood groups?

(a) 4, (b) 8, (c) 12, (d) 16.

- 36. In all the experiments of Mendel, the two alleles causing a trait were—
- (a) incompletely dominant, (b) codominant, (c) dominant recessive, (d) corecessive.
- 37. When red-flowered Mirabilis jalapa is crossed with white flowered Mirabilis jalapa, their offspring have pink flowers. This type of genotypic expression is called—
 - (a) dominant-recessive, (b) incomplete dominance, (c) corecessive, (d) codominance.
- 38. How many different kinds of eggs are produced by the \mathbf{F}_1 offspring from a cross between a pure strain of plants with yellow peas and a pure strain of plants with green peas?
 - (a) 8, (b) 4, (c) 2, (d) 1.
 - 39. A test cross is done to find out-
- (a) Whether two species can interbreed. (b) Whether a mating is fertile, (c) the genotype of an individual by testing for its DNA content,(d) the genotype of an individual by examining the phenotypes of its offspring from a particular mating.

40. Pleiotropy occurs when a gene has-

- (a) reversible effects on the phenotype, (b) a small effect on one trait, (c) a complementary gene elsewhere, (d) many effects on the phenotype.
 - 41. Diseases which are caused by pleiotropic genes are-
- (a) reversible by diet therapy, (b) reversible by gene therapy, (c) syndromes, (d) extremely rare.
- 42. In Mendel's dihybrid crosses, the two pairs of factors (genes) are situated on—
- (a) two separate pairs of homologous chromosomes, (b) a pair of nonhomologous chromosomes, (c) a pair of homologous chromosomes, (d) two sex chromosomes.
- 43. The syndrome in man in which an individual somatic cells contain only the one sex chromosome XO is known as—
 - (a) Turner, (b) Down, (c) Klinefelter, (d) Superfemale.
 - 44. To make a Karyotype, chromosomes are photographed during-
 - (a) meiosis, (b) interphase, (c) mitotic metaphase, (d) fertilization.
 - 45. A man receives his X chromosome from-
- (a) his father, (b) both his mother and father, (c) extranuclear DNA in her mother's ovum, (d) his mother only.
- 46. A man is colour blind and his wife is normal. What is the chance his son will inherit colour blindness?
 - (a) 0%, (b) 50%, (c) 100%, (d) 25%.
- 47. A woman's father has haemophilia which is an sex-linked recessive trait, but her husband is normal. What is the chance her son will have the haemophilia?
 - (a) 0%, (b) 25%, (c) 50%, (d) 100%.
 - 48. Giant mouse is produced by-
 - (a) gene duplication, (b) gene cloning, (c) gene mutation, (d) gene manipulation.
 - 49. Maximum formation of RNA occurs in-
 - (a) ribosome, (b) cytoplasm, (c) nucleolus, (d) nucleoplasm.
 - 50. Nucleotide arrangement in DNA can be seen by-
- (a) X-ray crystallography, (b) ultracentrifuge, (c) light microscope, (d) electron microscope.

Answers to Q. D -

[1] Pangenesis. [2] early 1800s. [3] 1866. [4] atypical plants in each generation [5] hybrids. [6] X-chromosome of male. [7] 0%. [8] Multiple alleles. [9] Red and green. [10] Recombination of linked genes. [11] XXY. [12] Klinefelter's syndrome. [13] Colour blindness. [14] 46. [15] sickle cell anaemia. [16] only when they are present on X-chromosome of male. [17] muton. [18] Gynandromorph. [19] Non-disjunction. [20] Haploid set of chromosomes. [21] Crossing over. [22] Mutagen. [23] Holandric genes. [24] A. E. Garrod. [25] Beadle and Tatum. [26] Transcription. [27] AUG. [28] Protein synthesis. [29] Harshey and Chase. [30] in the cytoplasm as well as in the nutochondria. [31] family pedigrees. [32] polygenic inheritance. [33] epistasis. [34] collaboration. [35] 4. [36] dominant recessive. [37] incomplete dominance. [38] 2. [39] the genotype of an individual by examining the phenotypes of its offspring from a particular mating. [40] many effects on the phenotype. [41] syndromes. [42] two separate pairs of homologous chromosomes. [43] Turner. [44] mitotic metaphase. [45] his mother only. [46] 0%. [47] 50%. [48] gene manipulation. [49] nucleolus. [50] X-ray crystallography.

Chapter 8: Photosynthesis

• [A] Long answer type questions:

1. Enlist the differet sites where photosynthesis is possible.

Ans. Photosynthesis can occur in all those tissues containing chlorophyll. It may be observed in the following organisms:

(1) Photosynthetic bacteria containing bacteriochlorophyll.

(ii) Blue-green algae containing phycobilins and chlorophylls.

(iii) Green algae of different types from unicellular to the dendrobial types.

(iv) Other forms of algae like brown, red, yellow green and diatoms.

(v) Bryophytes and pteridophytes (both in the gametophytes and majority of sporophytes).

(vi) Leaves of gymnosperms.

- (vii) Leaves, stipules, young shoot, sepals, assimilatory root, young fruit coat and tendrils of flowering plants.
- (viii) It can also occur in the specialized structures like the phylloclade of Opuntia, phyllode of Acacia, cladode of Asparagus.

2. What is meant by excitation of chlorophyll molecule?

Ans. The chlorophyll molecule is a magnesium porphyrin protein with a long hydrocarbon chain. It remains in ground state under normal conditions, but when exposed to the photon particles of sunlight, it becomes excited. Because of this excitation, the electrons from lower shell goes to higher energy state. The exposure to red light, takes it to energized first singlet level with a half life period of 10⁻⁹ second. But under the effect of blue light with shorter wave length, the chlorophyll molecule goes to high energy triplet state with a half life period of 10⁻³ second. From these states, the chlorophyll molecule comes back to ground state by liberating excess energy in the form of heat or as light in the forms of fluorescence and phosphorescence. At this time, the electons present in the outer shell come out and follow the cyclic or non-cyclic pathway to come back to the chlorophyll molecule again. During this process, ATP is generated by photophosphorylation and NADP is reduced to NADPH₂.

3. What are antenna pigments? What are their importance?

Ans. The different accessory pigments like carotene, xanthophyll, phycobilins are termed as antenna pigments. They are present in between the chlorophyll molecules, distributed in a 3 dimensional manner. Their hydrophilic porphyrin heads are embedded in protein while the lipophilic tails are suspended in the lipid layer.

They absorb extra wavelength of the solar energy that cannot be absorbed by chlorophyll; this extra energy is transferred to the chlorophyll and thereby photosynthetic efficiency is increased.

4. Name the different types of photosynthetic pigments and also the organisms where they are present.

- Ans. (i) Chlorophyll a is present in all photosynthetic organisms starting from prokaryotes up to flowering plants.
 - (ii) Chlorophyll b is present in all plants capable of producing starch.
- (iii) Chlorophyll c, d, e are present in different algal groups like brown algae, red algae and diatoms.

(iv) Phycobilins like c and r phycocyanine and phycoerythrine are present in bluegreen algae and red algae.

(v) Accessory pigments like carotene and xanthophyll also help in photosynthesis by trapping excess solar energy and transmitting it to the chlorophyll centre.

5. What is the nature of photosynthesis reaction? Can the process occur in absence of light?

Ans. The process of photosynthesis is a typical redox reaction, the equation is represented in the following way:

$$6CO_2 + 12H_2O \rightleftharpoons C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$$

In this equation, CO₂ is reduced to glucose, while water molecule is oxidised to oxygen.

The process of photosynthesis has two distinct phases, viz light phase and dark phase. The light phase is strictly dependent on light but the dark phase can occur even in absence of light. However, in darkness, the process cannot continue for a long time because in absence of light, the energy rich compounds like ATP and NADPH₂ are not generated, as a result of which, the dark phase cannot continue for long time in darkness.

6. Why the equation: $6CO_2 + 12H_2O \implies C_6 H_{12}O_6 + 6H_2O + 6O_2 \uparrow$ is not correct?

Ans. The equation $6CO_2 + 12H_2O \Longrightarrow C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$ is a fully balanced chemical equation, but it cannot explain the actual biological phenomenon of photosynthesis.

Reuben and Kamen have showed that the source of O_2 in photosynthesis is water. Now in the above equation, the 12 molecules of water directly give back 6 molecules of water, but the remaining 6 molecules of water caunot produce 6 molecules of O_2 . Hence the amount of water molecules should be doubled, *i.e.* 24 molecules of water is required. Thus the corrected form of equation is:

$$6CO_2 + 24H_2O \rightleftharpoons C_6H_{12}O_6 + 18H_2O + 6O_2$$

This equation can effectively explain the liberation of O₂ from water and the unutilized water molecules come out as end product.

7. What are the end products of photosynthetic light phase? How they are utilized in the dark phase?

Ans. The various end products of photosynthetic light phase are ATP, NADPH₂, O₂ and excess of unutilized water. These products are utilized in the following way:

ATP:

(i) It helps in the conversion of 3 PGA to 1, 3 DiPGA.

(ii) It also converts Ribulose-5-PO₄ to Ribulose 1, 5 Diphosphate.

NADPH₂: It helps in the conversion of 1,3 Diphospho glyceric acid to 3 phosphoglyceraldehyde and NADP is produced.

H₂O: (i) It helps in the conversion of Ribulose-1, 5 diphosphate to phospho glyceric acid by fixing atmospheric carbon dioxide.

(ii) It converts fructose 1,6 diphosphate to fructose-6-phosphate and inorganic phosphate is liberated in the process.

(iii) It also converts sedo hepteptulose 1, 7 biphosphate to sedoheptulose-7-phosphate and inorgaine phosphate is liberated in the process.

8. How Blackman's reaction varies from Calvin cycle?

Ans. The other name of the dark phase reaction is Blackman's reaction. It explains the fixation of CO₂ by Ribulose 1, 5 diphosphate and its conversion to Phospho glyceric acid, 3 phosphoglyceraldehyde, dihydroxy acetone phosphate and finally it condenses to hexose sugar.

But M. Calvin along with Bassam gave the complete explanation of the dark phase, in addition to the formation of hexose sugar by the above processes, the cycle also explains the regeneration of Ribulose-1, 5 diphosphate via different types of triose, tetrose, pentose, and heptose sugar molecules. They were awarded with Nobel prize for this discovery.

9. What is meant by Emerson's enhancement effect?

Ans. Emerson demonstrated that the presence of both red and blue light increases the rate of photosynthesis to a maximum extent than any one of the blue or red light. This is termed as Emerson's enhancement effect. This is because of the fact that the presence of both types of light activates both the photosystem I and II. Thus the production of energy rich compounds like ATP and NADPH, is enhanced. So, the process of cabon assimilation and the rate of photosynthesis increase.

10. What is meant by the Z scheme?

Ans. The Z scheme is the complete representation of photosynthetic light phase. It involves the two photosystems, viz PS I or P_{700} and PSII or P_{680} . The photon particles falling on both PSII and PSI liberates a pair of electrons. The one librated from P_{680} , breaks down water by photolysis and goes to replenish the gap created in PSI or P_{700} , uniting ADP + Pi on the way by photophosphorylation to produce ATP. The electron liberated from water replenishes the gap of P_{680} . The electron pair liberated from PSI comes to NADP and 2H comes from the breaking of water, liberating NADPH₂, while oxygn gas is liberated as by-product. The reaction is called Z scheme because of the involvement of an unknown Z carrier.

• [B] Distinguish between:

Chlorophyll is the

1. Distinguish between Chlorophyll and Carotenoid pigments Ans.

(1) Chrorophyti is the major	(1) Carotenoid hightent acts as me
photosynthetic pigment of green plants.	accessory pigment for photosynthesis.
(ii) Chlorophll can exist in the form	(ii) Carotenoid pigment exists in 2
of a, b, c, d and e.	forms, viz carotene and xanthophyll.
(iii) Chlorophyll pigments absorb the	(iii) Carotenoid pigments absorb
blue and red region of the visible	yellowish green region of the visible
spectrum.	spectrum.
(iv) The molecular weight of	(iv) Carotenoid pigments have
chlorophyll is greater.	comparatively low molecular weight.

Carotenoid

(i) Caratanaid nigment acts as the

2. Distinguish between Bacterial photosynthesis and Photosynthesis in higher plants.

Ans.

Bacterial photosynthesis	Photosynthesis in higher plants
(i) It takes place in the chromatophore of	(1) It takes place in the chloroplastid
bacterial cell. Work, the second of the	of higher plants.
(ii) The main pigments are bacterio-	(11) The main pigments are
viridin and chlorobium chlorophyll.	chlorophyll a and b, though c, d and e
	may also be present.
(iii) The process can occur even in	(iii) The process occurs in visible
ultraviolet and infra-red light.	light.
(iv) The process does not liberate oxygen.	(iv) It liberates oxygen.
(v) There is an additional reductive	(v) The additional reductive
decarboxylation pathway.	decarboxylation does not occur.
(vi) Starch is not produced.	(vi) Starch is produced as the end
	product.

3. Distinguish between Photophosphorylation and Oxidative phosphorylation. Ans.

Photophosphorylation	Oxidative phosphorylation
(i) It occurs in presence of sunlight.	(i) It occurs in presence of oxygen.
(ii) It occurs in the chloroplastid.	(ii) It occurs in the mitochondria.
(in) It is a branched reaction process	(iii) It is a linear process.
like a Z scheme.	
(iv) It liberates oxygen during	(iv) Oxygen acts as a terminal accept
photolysis of water.	or of electron, liberating water.
(v) The cycle each time liberates a	(v) Each cycle produces 3 ATP
molecule of NADPH, and 2 molecules	molecules.
of ATP. (vi) The different carriers are plasto-	(vi) The diffrent carriers are NAD,
quinone, plastocyanine, cytochrome b ₆ ,	FAD, Co-Q, Cytochromes b, c, a and a,.
cytochrome f, ferredoxin.	

4. Distinguish between Glycolysis and Photolysis.

Glycolysis	Photolysis
(i) It occurs during respiration in the	(1) It occurs during photosynthesis in
cytoplasm of a living cell.	the grana of chloroplastid of a plant cell.
(ii) One moleule of glucose splits into	(ii) One molecule of water splits into
two molecules of pyruvic acid.	2H and 1/2 O ₃ .
(iii) It does not require light.	(iii) It requires light.
(iv) ATP is generated in this process.	(iv) ATP is not gnerated during this
	processes.
(v) Glycolysis is known as Embden-	(v) Photolysis is a part of the Hill
Meyerhop-Parnas (EMP) pathway.	reaction.

5. Distinguish between Non-cyclic and Cyclic photophosphorylation. Ans.

Non-cyclic photophosphorylation	Cyclic photophosphorylation
(i) Two photosystems take part in this	(i) There is only one photosystems in
process.	this process.
(ii) It is a Z like pathway.	(ii) It is a cyclic pathway.
(iii) Oxygen is produced in this	(iii) Oxygen is not generated because
process due to photolysis.	photolysis does not take place.
(IV) NADPH, is generated.	(iv) NADPH, is not generated.
(v) It explains the complete photo-	(v) It is unable to explain the entire
synthetic light phase.	light phase.
(vi) It occurs in all higher plants.	(vi) It ocurs in photosynthetic
	prokaryotes.

• [C] Short answer type questions:

1. What are the antenna pigments?

Ans. They are accessory pigments like carotene, xanthophyll and phycobilins which are present along with chlorophyll and helps in increasing the absorption spectrum of photosynthesis.

2. How it was proved that water is the source of oxygen in photosynthesis?

Ans. Ruben and Kamen used the water containing O¹⁸ and showed that after photolysis, O¹⁸ is liberated; which proved that oxygen is liberated from water in photosynthesis.

3. How chlorophyll molecules are arranged within the chloroplastid?

Ans. The chlorophyll molecules are arranged in a 3 dimensional pattern within the grana thylakoid in such a way that their hydrophilic porphyrin heads are embedded in the protein layer, while their phytal tails are suspended in the lipid layer.

4. What are the different excited states of chlorophyll molecule?

Ans. The chlorophyll molecule under the effect of red light goes into the first singlet level with a half life period of 10⁻⁹ sec. But under the effect of blue light it goes to the 2nd singlet level and finally settles in the triplet state with a half life period of 10⁻³ second.

5. What are chlorosis and solarization of leaf?

Ans. Chlorosis is destruction of chlorophyll due to deficiency of magnesium or iron or various other reasons. But solarization is destruction of chlorophyll due to the exposure of the leaf to intense sunlight.

6. What are the first formed photosynthetic products in C_3 and C_4 plants?

Ans. The first formed photosynthetic product in C_3 plant is phosphoglyceric acid, which is a 3 carbon compound. But in C_4 plant, the first formed product is a 4 carbon compound called oxaloacetic acid.

7. What are the photosynthetic carbon fixation enzymes in C₃ and C₄ plants?

Ans. The photosynthetic carbon fixation enzymes of C_3 plant is RuDP carboxylase and in C_4 plant, it is PEP carboxylase.

8. What are the different organelles involved in the C₂ cycle?

Ans. The different organelles involved in C₂ cycle are chloroplastid, microbodies like peroxysome or glyoxysome and mitochondria.

9. What is CAM? What are the different stages of CAM?

Ans. The full form of Crassulacean Acid Metabolism. The two major stages of CAM are night acidification and day time deacidification.

10. Which plants keep their stomata open during night and why?

Ans. The plants belonging to family Crassulaceae keep their stomata open during night because they accumulate malic acid.

11. Why C4 cycle is more efficient?

Ans. The C_4 cycle is more efficient than C_3 cycle because the enzyme PEP carboxylase is activated at a lower concentration and it accumulates malic acid. Later the malic acid undergoes decarboxylation producing CO_2 at the site of mesophyll chloroplast. This activates the C_3 cycle, thus more sugar is synthesized and the process is more efficient in terms of photosynthesis.

12. What is kranz anatomy?

Ans. The kranz anatomy is found in the C_4 plants, this type of anatomy indicates two types of chloroplastid in the mesophyll and bundle sheath. e.g. Sugarcane, Panicum.

13. What are the different methods of 4-way carbon traffic?

Ans. The different methods of 4-way carbon traffic are C_3 cycle, C_4 cycle, C_2 cycle and Crassulacean Acid Metabolism or CAM pathway.

14. What is PQ?

Ans. The ratio of oxygen liberated and CO₂ taken in during photosynthesis is termed as photosynthatic quotient or PQ. For normal photosynthetic process, it is one.

15. What is meant by compensation point?

Ans. At a particular intensity of light, the rate of photosynthesis and respiration are equal to each other, which is known as light compensation point. Similarly the samething occurs at particular intensity of CO₂ concentration, it is termed as CO₂ compensation point.

• [D] Multiple choice type questions :

- 1. The excited chlorophyll molecule under the effect of red light goes to-
- (a) First Singlet Stage (b) Second Singlet stage (c) Triplet stage.
- 2. The value of PQ in case of photosynthesis is-
- (a) one (b) greater than one (e) less than one.
- 3. The example for antenna pigment is-
- (a) carotene (b) xanthophyll (c) phycobilin (d) all of them.
- 4. The head portion of the chlorophyll molecule is—
- (a) hydrophilic (b) lipophilic (c) hydrophobic in nature.
- 5. The process of photosynthesis occurs in the roots of —
- (a) orchid (b) Tinospora (c) both.
- 6. The most eficient carbon fixation pathway is-
- (a) C₂ process (b) C₄ process (c) C₂ process (d) CAM process.
- 7. The most common process of carbon fixation is—
- (a) C₃ cycle (b) C₄ cycle (c) C₂ cycle (d) CAM pathway.
- 8. The first photosynthetic product in C₂ cycle is—
- (a) Phosphoglycolic acid (b) Phosphoglyceric acid. (c) Phospho enol pyruvic acid.
- 9. The other name for photorespiration is-
- (a) C₂ cycle (b) C₃ cycle (c) C₄ cycle.

- 10. The major cause of compensation point is-
- (a) light (b) CO, (c) both.
- 11. Kranz anatomy is observed in-
- (a) grasses (b) lily (c) rose plant.
- 12. The major element required to form the head of chlorophyll molecule is-
- (a) Mg (b) Ca (c) Zn.
- 13. The primary site of photosynthesis is -
- (a) leaf mesophyll (b) leaf bundle sheath (c) young shoot (d) stipules.
- 14. The source of oxygen in photosynthesis is-
- (a) water (b) carbondioxide (c) glucose.
- 15. The other name for non-cyclic photo-phosphorylation is-
- (a) N scheme (b) Z scheme (c) S scheme.
- 16. Photosynthesis is a-
- (a) oxidation reaction (b) redox reaction (c) reduction reaction.
- 17. The other name for photolysis is-
- (a) Hill reaction (b) Blackman's reaction (c) Hatch Slack's reaction.
- 18. The complete dark phase is also called-
- (a) Calvin cycle (b) Blackman's reaction (c) Hill reaction.
- 19. The first formed product of photosynthesis in C4 plant is-
- (a) P.E.P.A (b) O.A.A (c) P.G.A. (d) RuDP.
- 20. The energy rich compounds produced in light phase and utilized in dark phase are—
 - (a) ATP (b) NADPH, (c) both.
 - 21. The process of photorespiration is brought about by-
 - (a) RuDP carboxylase (b) PEP carboxylase (c) RuDP oxygenase.
- 22. The highest number of carbon atoms present in sugar molecules produced during photosynthesis are—
 - (a) 6C (b) 4C (c) 5C (d) 7C.
 - 23. The crassulacean plants show the accumulation of-
 - (a) citric acid (b) malic acid (c) lactic acid.
 - 24. The purple sulphur bacteria is-
 - (a) photosynthetic (b) chemosynthetic (c) saprophytic in nature.

Answers to Q. D.

[1] 1st singlet stage ; [2] one ; [3] all of them ; [4] hydrophilic ; [5] both ; [6] C_4 process ; [7] C_3 cycle ; [8] phosphoglycolic acid ; [9] C_2 cycle ; [10] both ; [11] grasses ; [12] Mg ; [13] leaf mesophyll ; [14] water ; [15] Z scheme ; [16] redox reaction ; [17] Hill reaction ; [18] Calvin cycle ; [19] P.E.P.A. ; [20] both ; [21] RuDP oxygenase ; [22] 7C ; [23] malic acid ; [24] photosynthetic.

Chapter 9: Respiration

• [A] Long answer type questions:

1. Explain why TCA cycle and β -oxidation of fatty acids cannot operate in absence of oxygen..

Ans. TCA cycle and β -oxidation of fatty acids involve several oxidation reactions that are carried out by dehydrogenation (*i.e.* removal of hydrogen atoms from the substrate). These reactions are catalysed by dehydrogenases using NAD or FAD as the hydrogen acceptor which becomes reduced to NADH₂ or FADH₂. So, a steady supply of NAD and FAD is essential for operation of TCA cycle and β -oxidation. As the stock of NAD and FAD in a cell is limited, NADH₂ and FADH, must be quickly reoxidised to regenerate NAD and FAD for maintaining their availability. Regeneration of NAD and FAD from oxidation of NADH₂ and FADH₂ is accomplished through the electron transport system (ETS) in presence of O₂.

In absence of O_2 , the ETS cannot operate. So, regeneration of NAD and FAD from their reduced forms is not possible. As a result of this, the TCA cycle and β -oxidation also stop immediatly due to unavailability of NAD and FAD.

2. Why aerobic respiration is more efficient than anaerobic respiration? Explain.

Ans. In anaerobic respiration, the ETS cannot operate and oxidative phosphorylation does not occur. In this process, glucose molecules are incompletely catabolised through glycolysis only. So, for anaerobic breakdown of each molecule of glucose, only 2 molecules of ATP are gained through substrate level phosphorylation.

On the other hand, in aerobic respiration, the ETS and oxidative phosphorylation can operate; so glucose molecules are completely catabolised through glycolysis and TCA cycle. In this process, 38 molecules of ATP are gained through substrate level phosporylation and oxidative phosphorylation, for catabolism of each glucose molecule. Thus, aerobic respiration is much more (19 times) efficient than anaerobic respiration.

3. Although oxygen is utilized at the last stage of ETS, yet its absence completely stops aerobic respiration. Give reasons.

Ans. Complete aerobic respiration involves three processes—glycolysis, TCA cycle and electron transport system (ETS) whereas anaerobic respiration involves glycolysis but not the TCA cycle and ETS. In glycolysis, glucose is catabolised to pyruvic acid. In anaerobic respiration, the pyruvic acid is converted to lactic acid or ethanol for which presence of O₂ and ETS is not needed. In aerobic respiration, the pyruvic acid is converted to acetyl CoA by oxidative decarboxylation and the acetyl CoA is then completely catabolised through TCA cycle. The pathway of aerobic respiration is totally dependent on ETS because the ETS helps in regeneration of NAD and FAD from NADH₂ and FADH₂ which is necessary for maintaining the supply of NAD and FAD required for oxidative decarboxylation and TCA cycle.

In absence of O₂, the ETS does not operate because O₂ is the final oxidant (electron acceptor) in the ETS. When the ETS becomes inoperative in absence of O₂, the supply of NAD and FAD cannot be maintained. As a result of this, further breakdown of pyruvic acid through the aerobic pathway (i.e. oxidative decarboxylation and TCA cycle) stops completely and the pyruvic acid is diverted to the anaerobic pathway.

4. 'TCA cycle is designated as the final common pathway of catabolism'. Justify the statement.

Ans. TCA cycle is designated as the 'final common pathway' of catabolism because all the three types of energy yielding foods e g. carbohydrates, fats and proteins ultimately enter into this pathway for their complete catabolism. Carbohydrates are primarily catabolised through glycolytic pathway to produce pyruvic acid which is then converted to acetyl CoA that finally enters into the TCA cycle to complete the catabolism of carbohydrates. Fats are at first broken into glycerol and fatty acids. The glycerol is converted to pyruvic acid through glycolysis whereas the fatty acids are broken into several acetyl CoA molecules through β -oxidation. Thus both glycerol and fatty acids finally enter into the TCA cycle for their complete catabolism. Proteins are first broken into amino acids which then undergo deamination or transamination to produce keto acids like pyruvic acid, oxaloacetic acid and α -ketoglutaric acid that are finally catabolised completely through TCA cycle.

5. 'Yeasts are facultative anaerobes'. Justify the statement.

Ans. Facultative anaerobes are organisms which can survive both in presence as well as absence of O₂. That means, such organisms are capable of aerobic respiration as well as anaerobic respiration depending on availability of O₂, or demand of energy.

Yeasts are facultative anaerobes because they ordinarily respire anaerobically by alcoholic fermentation when they are not dividing (reproducing); but during cell division, they respire aerobically to meet the increased demand of energy.

• [B] Short answer type questions:

1. Who discovered—(a) ATP, (b) TCA cycle, (c) β -oxidation of fatty acids, (d) Coenzyme-A, (e) Alcoholic fermentation?

Ans. (a) Lohmann. (b) Hans Krebs. (c) Knoop. (d) Lipmann. (e) Louis Paseur.

- 2. Give another name of—(a) Glycolysis, (b) TCA cycle, (c) Electron transport chain.
- Ans. (a) Embden Meyerhof Parnas pathway (or EMP pathway), (b) Citric acid cycle. (c) Respiratory chain.
- 3. Mention the cellular site of—(a) Electron transport chain, (b) β -oxidation of fatty acids, (c) Alcoholic fermentation (d) Glycolysis, (e) TCA cycle.
- Ans. (a) Inner membrane of mitochondria (or Mitochondrial cristae). (b) Mitochondrial matrix. (c) Cytosol. (d) Cytosol. (e) Mitochondrical matrix.
- 4. Mention the reaction steps of aerobic oxidation of glucose in which oxidation occurs by dehydrogenation.

Ans. (i) Conversion of Glyceraldehyde-3-phosphate to 1,3 Diphosphoglyceric acid.

(ii) Conversion of Pyruvic acid to Acetyl CoA.

- (iii) Conversion of Isocitric acid to α-Ketoglutaric acid.
- (iv) Conversion of α-Ketoglutaric acid to Succinvl CoA.
- (v) Conversion of Succinic acid to Fumaric acid.
- (vi) Conversion of Malic acid to Oxaloacetic acid.
- 5. In which reactions of aerobic oxidation of glucose, CO₂ is released?

Ans. (i) Conversion of Pyruvic acid to Acetyl CoA.

- (ii) Conversion of Isocitric acid to α-Ketoglutaric acid.
- (iii) Conversion of α-Ketoglutaric acid to Succinyl CoA.

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6. Mention the reactions of glycolysis and TCA cycle in which ATP is produced directly by substrate level phosphorylation.

Ans. In glycolysis, ATP is produced directly by substrate level phosphorylation in two steps—

(1) Conversion of 1,3 Diphosphoglyceric acid to 3-Phospho glyceric acid.

(ii) Conversion of 2-Phosphoenol pyruvic acid to Pyruvic acid.

In TCA cycle, ATP is produced directly by substrate level phosphorylation in only one step - Conversion of Succinyl CoA to Succinic acid.

7. Which enzymes involved in pyruvic acid oxidation through TCA cycle, require NAD and FAD as hydrogen acceptor?

Ans. NAD is required for the following four enzymes-

(i) Pyruvic dehydrogenase. (ii) Isocitric dehydrogenase. (iii) α -Ketoglutaric dehydrogenase. (iv) Malic dehydrogenase.

FAD is required for only one enzyme known as Succinic dehydrogenase.

8. Name the tricarboxylic acids of the Krebs cycle sequentially.

Ans. Citric acid, Cis-aconitic acid and Isocitric acid.

9. (a) Name the enzyme of the electron transport system, which is capable of combining with oxygen. (b) In how many steps of the electron transport system, oxidative phosphorylation can occur?

Ans. (a) Cytochrome oxidase. (b) In three steps.

10. What are the end-products of anaerobic respiration in—(a) higher plant cells, (b) yeast cells, (c) skeletal muscle cells of vertebrates, (d) mammalian RBC and WBC (e) *Lactobacillus* bacteria?

Ans. (a) and (b): Ethanol, CO₂, H₂O and ATP.

(c), (d) and (e): Lactic acid, H,O and ATP.

11. Why 'alcoholic fermentation' and 'homolactic fermentation' are so named?

Ans. Alcoholic fermentation is so named because in this process ethyl alcohol is produced as the major end product. Homolactic fermentation is so named because the main end product of this process is lactic acid.

12. Which type of fermentation is used in production of—(a) liquor, (b) curd, (c) bakery-bread, (d) vinegar?

Ans. (a) Alcoholic fermentation. (b) Homolactic fermentation. (c) Alcoholic fermentation. (d) Acetic acid fermentation.

13. In which type of fermentation O, is used?

Ans. Acetic acid fermentation.

14. What are the end-products of (a) alcoholic fermentation, (b) homolactic fermentation and (c) heterolactic fermentation?

Ans. (a) Ethanol, CO2, H2O and ATP.

(b) lactic acid, H₂O and ATP.

(c) lactic acid, ethanol, CO2, H2O and ATP.

15. Name the products of TCA cycle containing 6, 5 and 4 carbon atoms sequentially.

Ans. 6C products—Citric acid, Cis-aconitic acid, Isocitric acid.

5C product—α-Ketoglutaric acid.

4C products—Succinyl CoA, Succinic acid, Fumaric acid, Malic acid and Oxalo-acetic acid.

16. What is known as—(a) energy currency of a cell, (b) Power house of a cell? Ans. (a) ATP. (b) Mitochondria.

17. Why photorespiration is not considered as true respiration?

Ans. Photorespiration is not considered as true respiration because from this process no ATP is gained, *i.e.* it cannot supply energy for any biological work.

18. In which plants photorespiration occurs?

Ans. Photorespiration occurs in C_3 plants in which Calvin cycle operates. Examples—plants of wheat, paddy, beet, bean etc.

19. Which cytoplasmic organelles take part in photorespiration?

Ans. Chloroplasts, peroxisomes and mitochondria.

20. Name the three main groups of enzymes that constitute the electron transport system for terminal respiration.

Ans. Pyridinoproteins, Flavoproteins and Cytochromes (or haemoproteins).

- [C] Multiple choice type questions:
- 1. The 'energy currency' of plant and animal cells is-
- (a) NADP, (b) Calorie, (c) ATP, (d) Sugar.
- 2. Cytochromes contain-
- (a) Copper, (b) Magnesium, (c) Manganese, (d) Iron.
- 3. The number of ATP molecules gained from complete oxidation of one molecule of pyruvic acid is—
 - (a) 2, (b) 8, (c) 15, (d) 30.
 - 4. The energy stored during formation of ATP from ADP and Pi is about-
- (a) 2500 3000 calories, (b) 7000 8000 calories, (c) 12000 12500 calories, (d) 20000 25000 calories.
 - 5. It is not wise to sleep under the trees at night because—
 - (a) They release oxygen at night.
 - (b) They use oxygen and release carbondioxide at night.
 - (c) They release both oxygen and carbondioxide at night.
 - (d) None of the above.
- 6. Which of the following is a common intermediate product of carbohydrate and fatty acid oxidation?
 - (a) Pyruvic acid, (b) Lactic acid, (c) Glucose-6-phosphate, (d) Acetyl coenzyme A.
- 7. Which of the following is a common product of aerobic respiration and alcoholic fermentation?
 - (a) Pyruvic acid, (b) Lactic acid (c) Citric acid, (d) Acetyl coenzyme A.
- 8. The mumber of ATP molecules gained from glycolysis in aerobic respiration is—
 - (a) 2 (b) 6, (c) 8, (d) 30.
- 9. During 24 hours, there is a time when plants neither give O₂ nor CO₂. This is at the time of—
 - (a) Midday, (b) Midnight, (c) Twilight, (d) None of the above.
 - 10. Cytochromes are—
- (a) Oxygen acceptors, (b) Hydrogen acceptors, (c) Electron acceptors, (d) None of the above.

11. Glycolysis occurs in-

(a) Mitochondria, (b) Cytosol, (c) Ribosome, (d) Golgi body.

12. Krebs cycle occurs within-

- (a) Ribesomes, (b) Mitochondria, (c) Golgi body, (d) Cytosol.
- 13. When yeast cells respire anaerobically, they produce—
- (a) Oxygen, (b) Carbon dioxide, (c) Nitrogen, (d) Lactic acid.
- 14. Aerobic respiration is more advantageous than anaerobic respiration because aerobic respiration—
- (a) Does not require sunlight, (b) Does not require molecular oxygen. (c) Produces O, as a waste product. (d) Releases more energy.
 - 15. In cellular respiration, oxygen is used as the final acceptor of-
 - (a) Carbon, (b) Hydrogen, (c) Nitrogen, (d) Iron.
- 16. During aerobic respiration, oxidation of glucose results in the formation of-
- (a) Hydrogen and water, (b) Carbondioxide and water, (c) Oxygen and carbon dioxide. (d) Hydrogen and oxygen.
- 17. More energy is released in aerobic respiration than in fermentation because fermentation—
- (a) Occurs in micro-organisms which have very few enzymes.(b) Causes incomplete oxidation of food. (c) Requires oxygen as the final oxidant. (d) Is a process in which only some kind of organic matter can be oxidised.
 - 18. To start cellular respiration, the living cells require a supply of-
 - (a) Glucose and ATP. (b) Glucose only. (c) Oxygen only. (d) Carbon dioxide only.
 - 19. Which is the final electron acceptor in aerobic respiration?
 - (a) Hydrogen, (b) Oxygen, (c) Cytochromes. (d) NAD.
- 20. Which of the following processes releases highest amount of usable energy per molecule of glucose broken down?
- (a) Fermentation in yeast cell. (b) Glycolysis in liver cell. (c) Formation of lactic acid in skeletal musle cell. (d) Fermentation in *Lactobacillus* bacteria.
 - 21. Complete oxidation of 1 gm mole of glucose releases—
 - (a) 6860 cals. b) 68600 cals. (c) 686000 cals. (d) 6860000 cals.
 - 22. Respiration occurs in-
- (a) All living cells both in light and dark. (b) All living cells in dark. (c) Only non-green cells in dark. (d) Only non-green cells both in light and dark.
 - 23. In respiration, pyruvic acid is-
- (a) Formed only when oxygen is available. (b) One of the products of Krebs cycle. (c) The end product of protein breakdown. (d) Broken down into a two carbon fragment and CO₂.
- 24. Incomplete breakdown of sugars in anaerobic respiration of plants results in the formation of
- (a) Pyruvic acid and water. (b) Lactic acid and carbondioxide. (c) Water and carbondioxide. (d) Alcohol and cabondioxide.
 - 25. The enzymes taking part in EMP pathway are present in-
- (a) Mitochondrial matrix.(b) Mitochondrial cristae.(c) Cytoplasmic matrix.(d) Both in mitochondria and cytoplasm.

- 26. Most of the energy is liberated in the cells by oxidation of carbohydrates when—
- (a) Pyruvic acid is converted into acetyl CoA. (b) Pyruvic acid is converted into CO₂ and H₂O. (c) Glucose is converted into pyruvic acid. (d) Glucose is converted into alcohol and CO₂.
 - 27. The link between glycolysis and Krebs cycle is-
 - (a) Citric acid. (b) Acetyl COA. (c) Succinic acid. (d) Fumaric acid.
 - 28. The common phase between aerobic and anaerobic respiration is-
- (a) TCA cycle. (b) Oxidative decarboxylation of pyruvic acid. (c) EMP pathway. (d) Krebs cycle.
 - 29. For respiration in plants-
- (a) ${\rm CO_2}$ is necessary. (b) Light is necessary. (c) Chlorophyll is necessary. (d) ${\rm O_2}$ is necessary.
 - 30. If alcoholic fermentation is allowed to proceed in a closed vessel-
- (a) Vacuum will result. (b) Gas pressure will develop due to excess of CO₂. (c) Gas pressure will develop because of excess of oxygen. (d) No change in pressure will occur.
 - 31. In glycolysis, the net gain is 2ATP and two molecules of-
 - (a) NADH, (b) NADPH, (c) FADH, (d) FMNH,
 - 32. Which of the following involves loss of two protons and two electrons?
 - (a) Carboxylation. (b) Dehydration. (c) Deamination. (d) Dehydrogenation.
 - 33. High energy compounds are-
- (a) Those which link exergonic to endergonic processes. (b) Produced when ATP loses two of its phosphates. (c) Produced in respiration only. (d) Sugars which release energy on oxidation.
- 34. Which one of the following is taken up by Krebs cycle after glycolysis is over?
 - (a) Pyruvic acid. (b) Acetyl CoA. (c) Citric acid. (d) Malic acid.
 - 35. Which one of the following statements is correct about respiration?
- (a) Air is inhaled into and exhaled from lungs. (b) Oxygen combines with carbon to form CO₂. (c) Oxygen combines with hydrogen to form water. (d) Oxygen must be available for oxidation.
- 36. Krebs cycle proper starts with the formation of a six carbon compound by reaction between—
- (a) Malic acid and acetyl CoA. (b) Acetyl CoA and Citric acid. (c) Oxaloacetic acid and acetyl CoA. (d) Fumaric acid and pyruvic acid.
 - 37. Oxidative phosphorylation occurs in-
- (a) Stroma of chloroplast. (b) Grana of chloroplast. (c) Outer membrane of mitochondria. (d) Inner membrone of mitochondria.
- 38. In the respiratory electron transport system, which is the terminal cytochrome that reacts with oxygen?
 - (a) Cytochrome-a. (b) Cytochrome-b. (c) Cytochrome-c. (d) Cytochrome-a₃.
 - 39. Oxidative phosphorylation is formation of-
- (a) ATP in respiration. (b) ATP in photosynthesis. (c) NADPH₂ in photosynthesis. (d) NADH₃ in respiration.

- 40. Synthesis of ATP in both oxidative phosphorylation and photosynthetic phosphorylation is essentially an oxidation process involving removal of energy from—
 - (a) Cytochromes. (b) Phytochromes. (c) Electrons. (d) Oxygen.
 - 41. The greatest importance of Krebs cycle is-
- (a) Synthesis of amino acids. (b) Synthesis of Vitamins. (c) Formation of ATP by oxidative phosphorylation. (d) To promote photosynthesis.
 - 42. In glycolysis-
- (a) Protein is converted to glucose. (b) Starch is converted to glucose. (c) Glucose is converted to fructose. (d) Glucose is converted to pyruvic acid.
 - 43. Which of the following combines with acetyl CoA to form citric acid-
 - (a) Oxalosuccinic acid. (b) Oxalo acetic acid. (c) Malic acid. (d) Aspartic acid.

Answers to Q. C -

[1] ATP. [2] Iron. [3] 15. [4] 7000 – 8000 calories. [5] They use oxygen and release carbondioxide at night. [6] Acetyl Co enzyme A. [7] Pyruvic acid. [8] 8. [9] Twilight. [10] Electron acceptors. [11] Cytosol. [12] Mitochondria. [13] Carbon dioxide. [14] Releases more energy. [15] Hydrogen. [16] Carbon dioxide and water. [17] Causes incomplete oxidation of food. [18] Glucose and ATP. [19] Oxygen. [20] Glycolysis in liver cell. [21] 686000 cals. [22] All living cells both in light and dark. [23] Broken down into a two carbon fragment and CO₂. [24] Alcohol and carbondioxide. [25] Cytoplasmic matrix. [26] Pyruvic acid is converted into CO₂ and H₂O. [27] Acetyl CoA. [28] EMP pathway. [29] O₂ is necessary. [30] Gas pressure will develop due to excess of CO₂. [31] NADH₂. [32] Dehydrogenation. [33] Those which link exergonic to endergonic processes. [34] Acetyl CoA. [35] Oxygen combines with hydrogen to form water. [36] Oxaloacetic acid and acetyl CoA. [37] Inner membrane of mitochondria. [38] Cytochrome-a₃. [39] ATP in respiration. [40] Electrons. [41] Formation of ATP by oxidative phosphorylation. [42] Glucose is converted to pyruvic acid. [43] Oxaloacetic acid.

Chapter 10: Growth, Metamorphosis and Aging

- [A] Long answer type questions:
- 1. What is growth? Describe in brief the diferent types of growth in living organisms.

Ans. Growth is defined as a permament increase in the length or volume of an organism, brought upon by an increase in its dry weight due to synthesis of new protoptasmic material.

Types of growth:

Growth occurs in various ways in living organisms, both in plants as well as in animals. These are given below:

(a) Growth may be classified on the basis of nature: On the basis of nature, growth may be classified as (i) Vegetative growth, (ii) Reproductive growth and (iii) Regenerative growth.

- (i)Vegetative growth (Somatic growth)—In this type, growth occurs by the division of somatic cells. We know that life starts with the formation of zygote. This zygote undergoes repeated mitotic division to form a muticellular embryo. Subsequently this embryo develops into an adult plant or animal individual.
- (ii) Reproductive growth After the vegetative growth has been completed, the organisms develop the reproductive growth. As a result, flowers of angiospermic plants and gonads (ovary and testes) in higher animals are developed. This reproductive growth is useful for the perpetuation of an organism.
- (iii) Regenerative growth—This type of growth is observed in plants and animals during repairing of lost or damaged part.
- (b) Growth may be classified on the basis of development of organs: On the basis of the nature of development of organs, growth may be classified as (1) *Isometric* and (ii) *Allometric*.
- (i) Isometric growth—This type of growth is uniform in all respects and the development is proportional on all sides. Hence, there is no change in the external structure as in fish.
- (ii) Allometric growth—This type of growth is not uniform in all respects; here some of the organs develop at a later stage. As for example in mammals, the reproductive organs develop at a later stage.
- (c) Growth on the basis of multiplication of cells: On this basis, growth nature can be classified as (i) Auxetic, (ii) Multiplicative and (iii) Accretionary.
- (i) Auxetic growth—This type of growth takes place mostly by increase in volume of cytoplasm; so there is no increase of the number of cells as for example in mematodes and tunicates.
- (ii) Multiplicative growth—It is purely by multiplication of cells. This is observed in case of man. In man, the new born baby has only 2 trillion cells which increases to 80 trillion cells in an adult individual.
- (iii) Accretionary growth—This type of growth is present in the post embryonic stage of higher animals. Here all the cells do not divide but only the totipotent cells divide to cause growth of the individual. As for example, mesenchyma and chondriocyte divide at a later stage.
- (d) Growth on the basis of duration: On this basis, growth can be classified as(i) Unlimited and (ii) Limited.
- (i) Unlimited growth—In this type, growth continues all through the life cycle. This type of growth is also known as *continuous growth* or *positive growth*. It is observed in perennial woody plants and also in some fishes.
- (ii) Limited growth—This type of growth is limited for a particular period in the life cycle of an organism, as seen in herbacious plants. This type is also known as discontinuous growth, as seen in insect where maximum growth is observed during metamorphosis. Sometimes, this type is also known as negative growth, because during scenescence, degrowth may be observed.
- (e) Growth on the basis of tissue types: This type of growth is observed commonly on plants, such as (a) apical growth, (b) intercalary growth and (c) lateral growth.
- (i) Apical growth—The growth of the apical region in shoot or root of plant is known as apical growth or *primary growth*. This type of growth is due to the apical meristem.

- (ii) Intercalary growth—The growth of the apex of the shoot may also takes place by the division of the intercalary meristem. Hence this type of growth of plants is known as intercalary growth.
- (iii) Lateral growth—It is also known as secondary growth. This secondary growth takes place from the cambium, as a result the thickness of a plant increases. Lateral growth commonly occurs in woody angiospermic plants.
 - 2. What is Grand period of growth? Describe its various phases.

Ans. The growth rate is not uniform all along the life cycle of plants and animals. The rate of growth changes with the age of an organism. The entire period in which the organism grows is known as the Grand period of growth.

Various phases of growth of an organism are as follows—(a) zero phase, (b) lag phase, (c) log phase, (d) reducing phase and (e) stationary phase.

- (a) Zero phase—Just after the formation of zygote, the organism does not grow. This is a very short phase which is technically known as zero phase.
- (b) Lag phase—This is also the short period where the preparation of growth takes place. In this phase, the cells of the organism only show changes in dimension but little division of cells is observed. The growth rate is very slow in lag phase.
- (c) Log phase—It is the actual growing phase. In this phase the growth rate-is very fast due to maximum division of the cells. This phase is also termed as the exponential phase. But the growth rate varies from one organism to other.
- (d) Reducing phase—In this phase, it has been observed that after a very fast rate of cell division, the rate of growth becomes gradually reduced in various organs.
- (e) Stationary phase—It is the last phase of growth, when the growth rate more or less becomes constant. This rate of growth might continue till the end of the life cycle in plants, but in animals, it might stop all together.
- 3. Write three external and three internal factors that control the growth of plants.

Ans. The rate of growth in living organisms is influenced by several factors which may be broadly classified into two major heads, the external factors and internal factors.

Important factors both external and internal are given below:

(a) External factors:

(i) Light: It has a profound influence on the growth of plants, because it controls the process of photosynthesis. High intensity of light may inhibit plant growth because the high intensity of light damages photosynthetic machinary. The duration of light mainly controls the reproductive growth or flowering. Hence on the basis of duration of light, the plants may be classified into three types, such as *Short day plants*, *Long day plants* and *Day neutral* plants. Short day plants reguire a short day light period of 8 – 10 hours for flowering, as for example tobacco, soybean. Long day plants require a long day light period of 14—16 hours for flowering, such as spinach, sugar beet. Day neutral plants do not have any specific requirement of day light period, such as tomato, sunflower. The direction of light may also induce the phototropic movement.

In general, plants which grow in a lighted place are called **photophilic** plants, such as sunflower. The shade loving plants are known as **photophobic** plant, such as moss, fern. The plants which grow both in the lighted condition as well as in the dark are called **photoneutral** plant.

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called photoneutral plant.

- (ii) Carbon di-oxide: It promotes photosynthesis in plant and thus the amount of food within the cell increases and growth is increased; but high concentration of carbon di-oxide may retard the growth of a plant.
- (iii) Soil conditions: The texture of soil, availability of nutrients, soil pH and the soil water directly influence the growth of a plant.
 - (b) Internal factors:
- (i) Nutrition: It is the process by which plants accumulate materials in their protoplasm and thereby the cell grows which initiates cell division. Thus growth increases with increase in accumulation of nutritive substances.
- (ii) Hormone: Hormones are the most important factors controlling growth in living organisms. In plants, auxin, gibberellin and cytokinin promote cell elongation and cell division. Hence these hormones are also called growth regulators.
- (iii) Chromosomal inheritance: All the individual characters including growth and cell division are controlled by genes and chromosomes. The inheritance of these characters by the progenies from the parents control their rate of growth. This is transmitted to the subsequent generations and thus establishes a trend of growth.
- 4. What is abscission? Where is abscission layer formed? How is it controlled? Ans. The detachment of leaves, flowers, fruits and twigs from the parent plant is known as abscission.

The abscission layer is formed at the base of the *petiole*, at the base of *fruit stalk* or *flower stalk*. This abscission is marked by few layers of lose, thin walled cells due to dissolution of the middle lamella by pectinase or cellulase enzyme. The vascular tissue is intact, but soon they get detached due to the weight of the plant part and the broken vascular tissue is quickly repaired by gum or resin deposition.

Control of abscission:

(a) Role of Auxin: The young leaves normally do not show abscission. But abscission is normally exhibited by older leaves. This happens because the lamina of younger leaves produce auxin or indole Acetic acid which suppresses abscission. It has been observed that if auxin is applied externally, then abscission is also suppressed. It has been proved that the relative concentration of auxin on the two sides of the abscission zone actually controls abscission. An equal concentration of auxin on the stem side and lamina side of the abscission zone usually promotes abscission. But higher concentration of auxin on the lamina side of the abscission zone retards abscission. This is regarded as auxin gradient hypothesis.

(b) Role of minor hormones:

The hormones like *abscisic acid* and *ethylene* also promote the activity of enzymes like pectinase and cellulase. As a result, they promote abscission. Hence abscisic acid promotes abscission of leaves and thereby prevents loss of water due to transpiration.

5. What is metamorphosis? How many types of metamorphoses are found in animals? What are the changes observed during the progressive metamorphosis?

Ans. Metamorphosis may be defined as a post embryonic development, which involves rapid changes in habit, habitat, morphology, physiology and behaviour of larva, so that the larva is transformed into an adult form having entirely different structure and living in different habitat.

Types of metamorphoses:

There are mainly four types of metamorphoses in animals, such as Progressive

metamorphosis, Retrogressive metamorphosis, Incomplete metamorphosis (hemimetabolous) and Complete metamorphosis (holometabolous). Progressive and retrogressive metamorphoses occur in chordates but Incomplete and complete metamorphoses occur in insects.

Changes during progressive metamorphosis:

In progressive metamorphosis, there are changes of simple larval organization into more complex organization of the adult.

Frogs and toads in amphibians show best example of progressive metamorphosis. Near the end of third month, the tadpole larvae of frogs and toads undergo many rapid changes. These changes occur in larval organs, such as some organs are lost and some undergo extensive modifications. As a result, tadpole larvae of frogs and toads change into a young frog or toad. During metamorphosis period, the following changes occur towards the end of larval period.

- (a) Ecological changes: Metamorphosis is associated with a transition from an aquatic to a terrestrial mode of life, such as in frogs and toads. Aquatic larva transforms into an young one. As a result, there is change in the feeding habit. Vegetarian habit of tadpole larva is converted to carnivorous habit of the young adult.
- (b) Morphological changes: The changes in the morphology of the tadpole larva during metamorphosis are partially *retrogressive* and partially *progressive*. Some of the retrogressive metamorphic changes are long tail along with the fin of the tadpole are gradually reduced and ultimately disappear; external gills are reabsorbed and gill clefts are closed; the horny teeth of the peri-oral disc are sheded off; the shape of the mouth changes and the gut is shortened.

Some of the *progressive metamorphic changes* are as follows:(i) two pairs of limbs are developed, (ii) tympanic membrane of the middle ear develops, (iii) the tongue is developed from the floor of the mouth cavity and the lungs are developed along with the modified vascular system for pulmonary respiration.

(c) Physiological and biochemical changes: Endocrine function of the pancereas starts at metamorphosis and in the liver, glucose is converted to glycogen. During metamorphosis, there is a profound change in the nitrogn metabolism, where urea is mainly produced in the adult instead of ammonia in the larval stage. The larval haemoglobin is replaced by adult haemoglobin. Visual pigments of the larva are also changed from porphyropsin to rhodopsin in the adult.

6. Describe the role of hormones in metamorphosis of chordates and insects.

Ans. Most probably the metamorphosis in chordate starts by environmental information which affects the larval brain through nervous system and the hypothalamus of brain integrates the information. Thus the neurosecretory cells in the hypothalamus are stimulated and produce thyroid releasing factor. This thyroid releasing factor stimulates the pituitary gland, which subsequently releases thyroid stimulated hormone (TSH). The TSH stimulates thyroid gland which then secretes two hormones, such as T_4 and T_5 . Both the hormones enter the blood circulation and their amount gradually increase. The increased amount of thyroid hormones causes the orderly sequence of tissue changes. As a result, there is transformation of aquatic tadpole larva into the young adult toad or frog, that comes to terrestrial surface. At the same time, a prolactin inhibitor is secreted by the hypothalamus. Thus prolactin concentration decreases and growth of larva declines and metamorphic changes occur. This type of metamorphosis

is regarded as progressive which is observed in amphibians, as for example toad, frog etc.

In insects, main hormone producing structures are *corpora cardiaca*, *corpora allata* and *prothoracic glands*. The role of the various hormones of these glands in moulting and metamorphosis of insects is given below

- (a) Brain hormone: Neurosecretory cells of the brain secrete the 'brain hormone' which is carried to the corpora cardiaca from where this hormone is released into the blood. This hormone stimulates the thoracic glands. Hence this hormone is also known as thoracotrophic hormone.
- (b) Ecdysone: Thorotracophic hormone of neurosecretory cells stimulates the thoracic glands, as a result a hormone is produced. This hormone is known as *Ecdysone* or, *Prothoracic gland hormone*. Ecdysone hormone is also known as **moulting** hormone.
- (e) Juvenile hormone: It is secreted by the corpora allata. As it ensures the retention of juvenile characters, so this hormone is known as juvenile hormone. This hormone maintains the larval state, so that the larval growth continues inhibiting metamorphosis. This hormone controls the growth, and moulting. Withdrawal of juvenile hormone initiates metamorphosis. We can say that juvenile hormone controls growth, moulting and onset of metamorphosis in insects.

• (B) Short answer type questions :

1. What is sigmoid curve?

Ans. Sigmoid curve is the growth curve of the living organisms which is commonly observed in plants and in some animals. This curve is obtained by plotting the rate of growth against time. Initially the growth rate is very slow during the lag phase, then the growth rate picks up during log phase, then it is gradually reduced and ultimately it becomes stationary i.e. parallel to the base line. Thus a typical 'S' shaped curve is obtained.

2. What is parabolic curve?

Ans. This type of curve is also regarded as growth curve. In this there is lag phase, log phase, reducing phase I, a short plateau, reducing phase II and finally zero phase. Thus the resulting curve appears like a parabolic curve or bell shaped curve. This type of parabolic growth curve is observed in bacteria and also in some animals.

3. What do you mean by differentiation and morphogenesis?

Ans. The process of formation of specialized cells from the existing undifferentiated cells during the initial stages of development is known as differentiation

The process of development of organs from existing mass of cells is termed as morphogenesis.

4. Write what you know about the phases of growth in living organisms.

Ans. There are three distinct phases of growth observed in plants and animals, such as cell division, cell elongation and cell maturation

- (i) Phase of cell division—The cells divide mitotically and help in the growth of the tissue. Examples—Meristematic regions of plants and growing regions of animals.
- (ii) Phase of cell clongation. Cells show increase in the amount of protoplasm and thereby enlarge in size.

(iii) Phase of cell maturation: The enlarged cells get modified and it helps them to perform the diverse functions of a multicellular organism.

5. Mention the role of temperature and oxygen in growth of plants.

Ans. Temperature controls the metabolic activity of a living cell. In general, the optimum temperature required for plant growth is 25°C = 30°C

Oxygen promotes respiration and releases energy required for the metabolic activity of a living cell and thus influences its growth.

6. Define abscission. How is it observed in plants?

Ans. The detachment of leaves, flowers, fruits and twigs from the parent plant is known as abscission.

Abscission is a distinct phenomenon in decidious trees and shrubs. In those plants all the leaves fall off during autumn by abscission and reappear during spring. In evergreen trees, the abscission is gradual; so there are always leaves present in the tree.

7. What is Photoperiodism? How is it beneficial to plants?

Ans. The response of a particular flowering plant to the effective day length with respect to flowering is known as photoperiodism

Photoperiodism helps in hybridization experiment. The mechanism of flowering is somewhat clearly understood. The physiological pre-conditioning can be achieved that induces flowering. On the basis of photoperiodism, plants can be classified as long day plant and short day plants.

8. What do you understand by the terms vernalization and devernalization?

Ans. The change in flowering habit by low temperature treatment is known as vernalization.

The positive effect of vernalization can be reversed by subsequent high temperature treatment, which is known as devernalization.

9. How many types of metamorphoses are there in animals?

Ans. There are mainly of four types of metamorphosis in animals. These are mentioned below:

Among Chordate animals there are mainly two types, namely-

(a) Progressive metamorphosis in toads and frogs (b) Retrogressive metamorphosis of lower chordate as in Ascidia.

Among Insects there are two types, namely-

(a) Hemimetabolous (incomplete metamorphosis : cockroach, grasshopper)

(b) Holometabolous (complete metamorphosis . moth, butterfly etc.)

10. What do you mean senescence and aging of living organisms?

Ans. Senescence and aging may be defined as the progressive deterioration of the structures and functions of fully efficient, matured organism with the passage of time. This ultimately culminates to the death of the organism.

11. Define the terms gerontology and gerontologist.

Ans. The branch of science that deals with aging is known as gerontology

The scientist studing the science of aging is regarded as gerontologist.

12. Biologists have described the bacteria as potentially immortal. Explain it.

Ans. A single celled bacterium when fully grown, it divides into two cells. This process is repeated again and again in bacteria. Thus no cell has ever been known to

die because of aging. Hence the process of aging does not occur in bacteria. Although a wide variety of environmental changes may kill a bacterium. So they are potentially immortal.

13. What are the factors that cause degenerative changes of senescence and aging?

Ans. Most biologists accept the idea that senescence and aging are the results from an interaction of both hereditary and environmental factors. Environmental factors are concerned with the effects of radiation, such as x-rays, cosmic rays etc. on the genes and chromosomes. Thus we can say that senescence and aging are caused by the gradual accumulation of genetic and biochemical defects.

14. What are the symptoms of aging in man?

Ans. Many bodily changes occur with aging. Few important symptoms of aging are as follows:

(a) Decreased muscular strength, (b) decreased lung capacity, (c) decreased pumping of blood from the heart, (d) decreased urine formation in the kidney and (e) decreased metabolic rate.

15. Write down the maximum life span of six wild mammals.

Ans. Name of the animals along with the maximum life span are given below

(a) Cat-28 years, (b) Dog-20 years, (c) Lion-30 years (d) Indian elephant-70 years, (e) Horse-62 years and (f) Rhesus monkey-29 years.

16. What do you understand by aging of annual plants?

Ans. In annual plants, the process of aging starts during fruiting. During this period, the rate of growth slows down and ultimately stops. Then the annual plants show the manifestations of aging. Manifestations of aging are: Chlorophyll disappear from the leaves, catabolism markedly rises and many other morphological changes follow.

17. What is 'Immunological theory' in relation to aging in higher animals?

Ans. This theory maintains that a programmed decline in immune system functions which leads to an increased vulnerability to infectious diseases. As a result, it causes aging and death.

18. What is 'Programmed senescence theory'?

Ans. According to this theory, aging is the result of the sequential switching on and off of certain genes with senesence being defined as the time, when age-associated deficits are manifested.

19. Why the muscular and connective tissues fail to work properly during senescence and aging of a man?

Ans. It has been observed that in senescence and aging, connective tissues and muscular structures fail to work properly due to the chemical changes in their protein molecules, such as in collagen and elastin. As a result of these changes, there is hardening of arteries. Hardening is more due to deposition of cholesterol and lipid in the connective tissue.

20 What is de-repression of genes? What its effect on aged people?

Ans. Genes which have withdrawned their functions in a fully differentiated cell, may suddenly start functioning again. This is known as de-repression of genes.

De-repression of genes will produce defective proteins. This error occurs in protein synthesis of aged peoples.

• [C] Multiple choice type questions:

1. The growth of the shoot apex in plants is known as-

(a) intercalary growth, (b) apical growth, (c) lateral growth, (d) limited growth.

2. In bacteria, the growth curve appears like a-

(a) sigmoid curve, (b) lag phase, (c) parabolic curve, (d) log phase.

3. Internal factor of growth in plant is-

- (a) temperature, (b) light, (c) oxygen, (d) hormone.
- 4. Secondary growth in plants takes place with the help of-
- (a) cambium, (b) primary tissue, (c) meristematic tissue, (d) apical meristem.
- 5. The growth of stem of a plant can be measured by-
- (a) simple microscope, (b) compound microscope, (c) arc indicator, (d) electron microscope.
 - 6. The abscission layer in plant is formed at the-
 - (a) base of the petiole, (b) apex of shoot, (c) apex of root, (d) vascular tissue.
 - 7. Long day plants, such as sugar beet require light period-
 - (a) 8 10 hours, (b) 14 16 hours, (c) 5 24 hours, (d) 10 12 hours.
 - 8. The larva of annelida is known as-
 - (a) miracidium, (b) hexacanth, (c) caterpillar, (d) trochophore.
 - 9. The type of metamorphosis that occurs in amphibia is known as-
- (a) hemimetabolous, (b) progressive metamorphosis, (c) holometabolous, (d) retrogressive metamorphosis.
 - 10. Amphibian metamorphosis generally occurs at a temperature between-
 - (a) 20 25°C, (b) 10 15°C, (c) 25° 30°C, (d) 5 10°C.
 - 11. In toads, metamorphosis change the feeding habit to-
 - (a) vegetarian, (b) carnivorous, (c) frugivorous, (d) sanguinivorous.
 - 12. Complete metamorphosis in insects takes place in-
 - (a) cockroach, (b) grasshopper, (c) cicada, (d) butterfly.
- 13. Neurosecretory cells of the brain of insects secrete the hormone known as—
- (a) thoracotrophic hormone, (b) thyroxine hormone, (c) juvenile hormone, (d) prothoracic gland hormone.
 - 14. Pheromones are secreted from exocrine glands mainly by-
 - (a) amphibians, (b) annelids, (c) insects, (d) molluscs.

Answers to Q. C.

[1] apical growth. [2] parabolic curve. [3] hormone. [4] cambium. [5] arc indicator. [6] base of the petiole. [7] 14 – 16 hours. [8] trochophore. [9] progressive metamorphosis. [10] 20 – 25°C. [11] carnivorous. [12] butterfly. [13] thoracotrophic hormone. [14] insects.

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Chapter 11: Origin and Evolution of Life

• |A| Long answer type questions:

1. Why do almost all modern biologists reject Lamarck's theory of evolution?

Explain.

Ans. Jean Baptiste Lamarck, a well known French naturalist, proposed in 1809 a theory of evolution by inheritance of acquired characteristics. The theory states the following four basic propositions.

(a) Organisms and their organs have a natural tendency to increase continuously in

size in subsequent generations.

(b) Changes in environmental conditions directly influence the organisms and tend to affect their structural organisation according to the need. As a result, new structures are developed in the organisms.

(c) An organ which is used constantly tends to become more developed; whereas

the organ which is not used, gradually tends to become degenerated.

(d) Changes or modifications produced by the above principles during the life time of an individual are transmitted to the next generation and after a number of generations

new species is developed.

Lamarck used the example of giraffe's neck and forelimbs. The ancestors of giraffe were having a small neck and small forelimbs. Due to decrease of surface vegetation, they were bound to stretch their neck and forelimbs to collect the leaves from tall trees. This resulted in the slight elongation of neck and forelimbs. Lamarck explained, whatever they acquired in life time that was transmitted to the offspring of the next generation. Thereafter, the next generation acquired during life time more elongation of neck and forelimbs, that was passed to the next generation. In this way, these characters with more perfection passed on from generation to generation through herditary factors. As a result of which, modern giraffe with long neck and forelimbs developed.

Everything we now know about genes indicates that there is no way that changes in body cells or somatic cells can cause specific changes in the genes or chromosomes of germ cells or reproductive cells. Modification of an individual's somatic cells of an organ during its lifetime are not passed on to the next generation. All changes in the gene or chromosome of a reproductive cell or germ cell are random changes or mutations rather than direct changes that improve the organism's adaptation to its environment. Natural selection, acting on these random changes, removes from the population those mutations, that reduce an individual's fitness, so that the mutations or new alleles, that persist either have no effect on or improve an organism's adaptation to its environment. Giraffes that could not reach the leaves on tall trees did not get enough food to survive. Hence their genes or chromosomes were not transmitted to the subsequent generations. Giraffes with longer neck and forelimbs got more food and transmitted more genes to subsequent generations.

Little evidence has appeared in the support of the theory of evolution by inheritance of acquired characters. Hence most biologists reject the Lamarck's theory of evolution completely.

2. How did the Galapagos finches (Darwin's finches) contribute to the development of Darwin's ideas of evolution?

Ans. In 1831, Charles Darwin accepted an unpaid post of naturalist in the survey-

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ship H. M. S. Beagle, which spent the next five years in sea charting at the East Coast of South America. In 1836 he returned to England via Galapagos islands. While returning Darwin stayed five weeks in the Galapagos islands. He observed that thirteen species of finches are found only in the Galapagos islands and one species is found only on Cocos island, which is about 1000 km northeast of the Galapagos islands. One species of Cocos island gave rise to thirteen species in the various Galapagos islands. But no such divergence occurred in case of the single species of Cocos island because one finch species still exists there. He was struck by the similarities shown by the flora and fauna of the Galapagos islands and mainland. In particular he was intrigued by the characteristic distribution of species of finches.

Darwin was impressed not only by the distribution of finches, but also the differences in body size, beak shape and feeding habits among these closely related finches. Some of the species were restricted to just a single island and others were seen on several islands. By and large, these finches, as well as other plants and animals of the Galapagos islands, resembled the plants and animals of South America which is located approximately 1000 km to the east of Galapagos islands. He wondered, if these finches were created specifically for the Galapagos islands, then why these finches resembled the organisms of South America rather than the organisms of other countries say Asian or African. These islands of Galapagos are volcanic in origin, so they are younger than South America. Hence Darwin speculated that a few individuals of an ancestral finch species in South America flew to these islands of Galapagos shortly after the emergence of islands from the ocean floor. People from the mainland also migrated to these newly developed islands and gradually they spread to all the islands. These people became fragmented into separate populations on separate islands. Each isolated population experienced a unique set of environmental conditions with a unique set of selective pressure. As a result, each gradually evolved a unique set of adaptations.

Darwin collected a great deal of biological data concerned with variation between organisms. He was convinced from these data specially the finches of Galapagos islands that species were not immutable.

3. How does the modern synthetic theory differ from the Darwinian theory of evolution? Explain.

Ans. Darwinian theory of evolution has undergone evolutionary transformation but the basic theory of evolution developed by Darwin still remains undisputed. New facts and factors which are operating on organisms during evolutionary changes were unknown to Charles Darwin. All informations acquired from modern researches have been incorporated into a comprehensive theory of evolution by natural selection. Information acquired since 1959 has refined, but not substantially attered, the basic structure of Darwin's theory of evolution, Important changes include a redefined unit of evolution a knowledge of genetics, and their appreciation, kinds of mortality or differential reproduction produce evolutionary change.

Darwin recognized the species as the unit of evolution. Because a species is a group of similar organisms that can mate and reproduce with one another. We now know that most species are subdivided into local populations with variable degrees of reproductive isolation. Individuals of the same species are in different populations, separated from one another in such a way that it is highly unlikely that they will meet and reproduce. Hence the unit of evolution is now regarded as the *population*. Evolution may be defined

as a change in the frequency of an allele within a population in response to local environmental conditions.

An important addition to Charles Darwin's theory of evolution is knowledge about the physical basis of heredity, which is based on genes and how these genes are transmitted from parent to the subsequent generations. The development of evolutionary studies has attained its modern stage through the progress of genetics. The synthesis of modern genetics with the basic principles of Darwinian concepts has led to the creation of the Synthetic theory. Synthetic theory refers to the merging of evolution and genetics. We now know that differences among individuals of a species result from an accumulation of mutations in the population and from the recombination of genes during sexual reproduction. Thus each offspring inherits a group of genes and interactions between genotypes and environmental factors determine the phenotypes. These phenotypes or expressed characters influence the population, individuals reproduce more successfully and these genes increase in frequency within the local population.

Darwin expressed that individuals with certain characters will be more successful in the struggle for existence and leave more offsprings than other individuals in the species. But now this is not always true. Many mortalities in populations are non-selective. Catastrophes, such as flood, fires, earthquake etc. can remove the majority of individuals in a population, regardless of their genotypes. Chance factors, such as the few individuals that inhabit an island, play a greater role in evolution than Darwin realized.

G. L. Stebins has drawn an interesting analogy, in which gene mutation has been considered as the fuel (petrol) of the autovehicle, genetic recombination as the engine and natural selection as the driver. The chromosomal changes have been compared to the accelator and reproductive isolation has been considered as the driving signs and speed limits of the highway.

4. Write in short on the efforts for conservation of biodiversity in India.

Ans. Indian sub continent shows wide range of biodiversity. India is the centre of diversity of animals and plant species. It is a homeland of 167 cultivated species and 320 wild relatives of crop plants. India is the centre of diversity of animal species, such as mithun, buffalo, camel etc. as well as plant species, such as crop plants, fruit plants and vegetables. In India, there are secondary centre of domestication for some plants, such as potato, maize and tobacco, as well as some animals, such as horse, cattle, sheep etc.

We know that ecosystems are undergoing change due to pollution, invasive species, over-exploitation by humans and climatic changes. Now we are beginning to understand that diversity at all levels, namely gene pool, species and biotic community is important and biodiversity needs to be conserved. The most effective mechanism for conserving biodiversity is to prevent further destruction of habitats by us.

In India, the conservation of biological diversity is being carried out through Biosphere reserves, National parks, Wildlife sanctuaries and other protected areas by the Ministry of Environment and Forests. Biosphere reserves are a special category of protected areas of land and coastal environments, wherein people are an integral component of the system. Biosphere reserves are dealing with the conservation of ecosystems and the genetic resources. There are 16 biosphere reserves in India. A biosphere reserve consists of natural or core zone, buffer zone and transition or manipulation zone. Core zone of biosphere remains undisturbed and legally protected

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area; buffer zone remains surrounding the core area. In this area, research and educational activities are allowed, it is further divided into Baffer Zone I and II. The outermost area is regarded as transition or manipulation area. It is an area of active cooperation between the management and the local people. As a result, activities like cropping, forestry, recreation and other economic uses continue in harmony with conservation goals.

Forest management system involves forest departments and local communities. This management enables the tribal people and local communities to have access to non-wood forest products and at the sametime protect the forest resources.

The National Bureau of plant, animal and genetic resources has a number of programmes to collect and conserve the germplasms of plants and animals. Botanical and zoological gardens have large collections of plant and animal species in different climatic regions of India.

Different types of terrestrial animals as well as diverse varieties of crops and medicinal plants are also being conserved successfully by the tribal people. This conservation work is also being done by the women either individually or with various non-governmental agencies. They are playing a very important role in the conservation of agrobiodiversity. In India, a programme is under preparation to develop a system of community registers of local informal innovations particularly genetic resources as well as natural resource management. The National Innovation Foundation (Ahmedabad) is doing commendable work in this respect.

• [B] Short answer type questions :

1. What do you mean by allopatric and sympatric speciation?

Ans. Origin of new species in geographically isolated populations is known as allopatric speciation whereas origin of new species in a population occupying the same geographical area is known as sympatric speciation.

2. What are divergent evolution and convergent evolution?

Ans. Divergent evolution is defined as a formation of different structures from a common ancestral form.

Formation of similar characters among the unrelated groups of oganisms is regarded as convergent evolution.

3. What is sibling species? Cite an example.

Ans. Two species which are morphologically almost identical but do not interbreed, are known as sibling species.

Example: Two species of fruit fly (such as *Drosophila pseudoobscura* and *Drosophila persimilis*) are morphologically similar but they fail in cross fertilization.

4. What is the role of gene flow or gene migration in evolution?

Ans. Variation is the raw material of evolution. This variation among the members of the same species is caused by many evolutionary agents of which gene flow or gene migration is one of them. Hence genetic variation like gene flow is the pre-requisite of evolution. Then the Natural selection acts on this genetic variation.

5. What do you mean by evolutionary agents? Mention the names of those agents.

Ans. The forces that change the allele and genotype frequencies in a population are called evolutionary agents.

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Name of evolutionary agents are given below-

(a) Mutation, (b) Recombination, (c) Gene migration or gene flow, (d) Genetic drift and, (e) Nutural selection.

6. In which conditions, mimicry is more effective?

Ans. (a) Mimicry is more effective in the forest area. (b) Mimicry is more effective where mimic and model operate together in the same geographical area. (c) Mimicry is more effetive in structure and behaviour.

7. What are the causative factors of mimicry?

Ans. It has been stated that the resemblance between the mimic and the model is due to the effect of similar environmental factors. Some scientists have stated that mimicry develops due to a single gene mutation. Resemblance between the mimic and the model is perfected by the action of modifying genes and natural selection. Hence mimicry develops due to the action of genes and natural selection.

8. Why the ancestor of man gave up tree life? What are the subsequent changes due to ground dwelling habit of pre-historic man?

Ans. The ancestor of man gave up tree life and became ground dwellers because of the following reasons—

The increased competition on the trees and the decrease in forest area caused by glaciation during the pleistocene epoch were the two factors that compelled them to change the habitat from tree to the ground.

Pre-historic man evolved further to meet the requirements of ground dwelling habits, hence subsequent changes occurred in many organs, such as hind limbs became modified for bipedal locomotion with erect posture, perfection of binocular vision and absence of tail. The hands were free from the job of carrying the weight of the body, so that hands could be used for different kinds of work. As a result of development of cerebral cortex of brain, the power of reasoning and memory developed. These changes of the pre-historic men gave an advantage to them in natural selection. Thus there was a rapid change from prehistoric man to modern man.

9. What are the importance of Proconsul fossil and fossil of Cro-Magnon man?

Ans. Proconsul is one of the oldest fossils discovered from South Africa. This fossil skull bears characters of both man and ape. So it indicates a common ancestory of man and ape.

Fossil of Cro-Magnon man was discovered from France. Cro-Magnon man flourished between 50,000 and 20,000 years ago. They developed a high degree of culture and craftsmanship. However, it is not known whether the Cro-Magnon man was the direct ancestor of the modern man or just an offshoot of the main branch.

10. Write in short about the fossil record of prehistoric man, Pithecanthropus erectus.

Ans. This fossil was discoverd from Java, hence it is commonly known as Java apeman. The fossil record indicates that the brain capacity of Java ape-man is about 900cc which is between great apes and modern man. The skull of this fossil indicates that the supra-orbital ridges, forehead and face are ape-like but the dentition is like modern man. They exhibited erect posture. The general opinion is that *Pithecanthropus* was intermediate between *Australopithecus* and *Homo sapiens* (modern man) and existed in the Pleistocene epoch.

11. How many types of biodiversity are there? Mention their names only—Ans. There are three types of biodiversities.

They are:

(a) Genetic diversity, (b) Species diversity, (c) Community and ecosystem diversity. All these types of biodiversities are interrelated to each other, yet they are distinct enough.

12. What is the importance of genetic diversity in evolution?

Ans. Genetic diversity is said to be the variations in genes and chromosomes within the species. The genetic variation enables a population to adapt to its environment and to respond to natural selection. The speciation or origin of new species depends on the amount of genetic variation. The genetic variation is playing a very important role in the maintenance of diversity at species and community levels.

13. What are the benefits of biodiversity in modern agriculture?

Ans. Modern agriculture is benefited by biodiversity in three ways-

(a) Biodiversity or biological diversity is the source of new crops. (b) It is a source material for breeding improved varieties of species. Domesticated species crossbreed with their wild relatives to improve their traits. (c) It is a source of new biodegradable pesticides.

14. Mention the main benefits of biosphere reserves.

Ans. (a) Biosphere reserves ensure the conservation of landscapes, ecosystems, species and genetic resources. (b) Biosphere reserves are promoting economic development. (c) Biosphere reserves are providing research work, education and information exchange.

• [C] Multiple choice type questions:

1. Charles Dawin's book, 'On the origin of species by means of Natural Selection' was first published in—

(a) 1900, (b) 1859, (c) 1809, (d) 1779.

- 2. Aristotle believed that all things can be arranged in order of gradual complexity and there is no possibility of position change within the fixed order. This view of life is known as—
- (a) natural selection, (b) philosophy of essentialism, (c) inheritance of acquired characters, (d) Scala Naturae.
 - 3. Darwin found that South American fossils are most similar to-
- (a) Oriental fossils, (b) Australian fossils, (c) living species of South America, (d) living species of North America.

4. The primary misson of the Voyage of H. M. S. Beagle was to-

- (a) chart South American coastline, (b) carry arms to the New World, (c) disprove the theory of Lamarck, (d) find out more species in the world.
 - 5. The best test of the relationship between species is in the similarity of their—
 - (a) anatomy, (b) development, (c) mating behaviours, (d) DNA and proteins.
- 6. Major Populations of *Biston betularia* (peppered moth) of England changed from light individuals to dark individuals between 1848 1898. The selective agent causing the change was—
 - (a) birds, (b) tree bark, (c) toxins from smoke of industry, (d) humans.
- 7. After industrial pollution, lichens (light colour) were destroyed on the bark of the trees, the survival of the dark-coloured peppered moths inercased, because they were—
- (a) protected from lichen poisons, (b) protected from predators, (c) protected from carcinogens, (d) more robust.

8. Stanley Miller synthesized amino acids from a mixture of-

(a) Hydrogen, ammonia, methane and water vapour, (b) Ammonia, methane and oxygen, (c) Hydrogen, nitrogen and water vapour, (d) Hydrogen, hydrogen cyanide and oxygen.

9. Which element was not present freely in the primitive atmosphere at the

time of origin of life?

(a) Hydrogen, (b) Carbon, (c) Water, (d) Oxygen.

10. At present, life cannot arise from inorganic materials because of-

- (a) a very high amount of oxygen in the atmosphere, (b) high degree of environmental pollution, (c) absence of raw materials, (d) very low atmospheric temperature.
 - 11. Chemical theory about origin of life was proposed by-
 - (a) Pasteur, (b) Darwin, (c) Lamarck, (d) Haldane and Oparin.
 - 12. First photosynthetic organisms to develop on earth were-

(a) cyanobacterla, (b) diatoms, (c) bacteria, (d) green algae.

- 13. Presence of salts in animal body fluid gives an inference that life originated in the—
 - (a) rain water, (b) primitive ocean, (c) salt solution, (d) none of the above.

14. Golden age of reptiles was-

- (a) Coenozoic, (b) Palaeozoic, (c) Mesozoic, (d) Proterozoic.
- 15. Resemblance between widely different groups due to a common adaptation is—
- (a) divergent evolution, (b) parallel evolution, (c) retrogressive evolution, (d) convergent evolution.
 - 16. Birds and mammals were evolved during the period of—

(a) Jurassic, (b) Permian, (c) Oligocene, (d) Carboniferous.

17. Who gave the principle that population tends to multiply more rapidly than food supply?

(a) Haldane, (b) Malthus, (c) Darwin, (d) Lamarck.

- 18. Modern breeds of domestic dog have evolved through-
- (a) Natural selection, (b) Isolation, (c) Sexual selection, (d) Artificial selection.

19. Darwin was most influenced by-

(a) essay on population by Malthus, (b) theory of germplasm by Weismann, (c) theory of acquired characters by Lamarck, (d) theory of origin of species by Wallace.

20. Darwin's theory of Natural selection dealt on-

- (a) Inheritance of acquired characters, (b) Role of environment on evolution, (c) Natural selection acting on favourable variations, (d) Changes in gene resulting in heritable variations.
 - 21. Frequency of a character increases when it is-

(a) recessive, (b) inheritable, (c) dominant, (d) adaptable.

- 22. Closely related, morphologically similar, reproductively isolated sympatric populations are designated as—
 - (a) sibling species, (b) clines, (c) demes, (d) clones.
- 23. The most important evidence since Darwin that bears on his theory has been in the area of—
- (a) comparative anatomy, (b) palaeontology, (c) genetics, (d) geographical distribution.
 - 24. The unit of evolution is now known as-
 - (a) species, (b) population, (c) individual, (d) family.

25. Darwinian fitness of an organism is a measure of-

(a)number of offspring it produces, (b) its lifespan, (c) its ability, relative to others in the population, to pass its genes to the next generation, (d) its physical vigour.

26. A change in the relative abundance of an allele within a population, over a

succession of generations, is called-

(a) macroevolution, (b) microevolution, (c) phylogenetic evolution, (d) coevolution.

27. Microevolution can be measured by comparing observed allelic frequencies with those predicted by—

(a) the Hardy-Weinberg equation, (b) Mendelian ratios, (c) all known environmental

factors, (d) chance.

- 28. A potential danger to a population that has been greatly reduced in number is the—
- (a) tendency towards assorted mating, (b) reduced gene flow, (c) Hardy-Weinberg disequilibrium, (d) loss of genetic variability.

29. Another term for adaptive evolution is-

(a) speciation, (b) macro-evolution, (c) micro-evolution, (d) clinal change.

30. Natural selection acts on an organism's-

(a) phenotype, (b) combined genotype, (c) dominant alleles, (d) recessive, homozygous alleles.

31. Stabilizing selection favours-

(a) intermediate forms of a trait, (b) environmental differences, (c) one extreme form over the other extreme form and over intermediate forms of a trait, (d) both extreme forms of a trait.

32. Disruptive selection favours-

- (a) environmental differences, (b) both extreme forms of a trait, (c) intermediate forms of a trait, (d) one extreme form over the other extreme form and over intermediate forms of a trait.
- 33. In some birds, the males are more colourful than the females. The selective agent producing the evolution of such conspicuous features is—

(a) predators, (b) climate, (c) females, (d) humans.

34. Directional selection favours-

(a) intermediate forms of a trait, (b) both extreme forms of a trait, (c) one extreme form over the other extreme form and over intermediate forms of a trait, (d) environmental differences.

35. The formation of a new species through change in a single lineage is known

as—

- (a) divergent evolution, (b) phyletic evolution, (c) allopatry, (d) convergent evolution.
- 36. The formation of two species from one ancestral species is known as—
 (a) phyletic evolution, (b) allopatry, (c) divergent evolution, (d) convergent evolution.

37. Membrs of a biologic species are potentially able to-

(a)interbreed, (b) introgress, (c) express all the same genes, (d) compete.

38. A prezygotic isolating mechanism prevents successful-

(a) zygote development, (b) fertilization, (c) reproduction of hybrids, (d) gamete production.

39. Reproductive isolation in sympatric speciation develops without a-

(a) barrier to gene flow, (b) change in chromosome number, (c) barrier to mating, (d) geographical barrier.

40. Sympatric speciation occurs most commonly in-

(a) fishes, (b) plants, (c) birds, (d) mammals.

- 41. A postzygotic isolating mechanism prevents successful
- to appear or budge opined county if accounting the temperation
- 42. In allopatric speciation, the initial barrier to gene flow is
- tax to straphy that I would depend come of the confidence
- 43 Marsupial manimuls moved from South America to Australia via
- La Africa de Matrias in contratellos de the Grapios Achiepetico
- 44. Closely related organisms with very different traits have experienced
- (a) convergent evolution (b) divergent volution (c) parallel evolution (d) coevolution
- 45. Similar traits resulting from similar selection pressures acting on similar gene pool is—
- evolution.
 - 46 Macroevolution is the evolution of
- organisms, (d) macromolecules. Plant to
 - 47. Australopithreus lassil skull is collected from
 - cas Southern Africa (b) China ici Liva (b) Cornors
 - 48 Scientific name of modern man is
- (4) Pethecanthropus erectus (b) II mo sapiens (c) Sinanthropus per new 1d) Homo neardermachus
- 49 The fossil of Trchaeopterix is known as connecting link because it has characters between—
- (a) Reptiles and manimals (b) Fishes and amphibians, (c) Birds and reptiles, (d) Chordates and non-chordates
 - 50. Study of fossils comes under-
 - ta) Herpetology (b) Loobis, logy (c) Palaeogeography (d) Palaeontology

Answers to Q. C

[1] 1889 [2] Seeth, Some of St. By the newspecial of Seath America [4] chart South American constant [5] DNA . Type to is [6] tooks [7] protected from predators [8] Hydrogen ammonia in the country after vapour [9] Oxigen [10] a very high amount of oxygen in the atri- quere [11] Haldane and Opanii [12] C can obacteria [13] princitive ocean [14] M. ozeac [15] convergent evolution [16] Junas ne [17] Malinus [18] Artificial selection [19] essay on population by Malthus [20] Natural election acting on favourable variations [21] adaptine [22] sibling species [23] senetics [24] population [25] its ability, relative to others in the population to pass its genes to the next generation [26] microevolution [27] The Hardy Weinberg equation [28] ioss of genetic variability [29] micro evolution [30] phenotype [31] intermediate forms of a trait [32] both extreme forms of a trait [33] temates [34] one extreme form over the other extreme form and over interns bate forms of a trait [35] physelic evolution [36] divergent evolution [37] interbreed [38] tertilization [39] geographic barrier [40] plants [41] development survival [42] reographic [43] Antarctica [44] divergent evolution [45] para iel evolution [46] n. nor events occurring over geologic time [47] Southern Africa. [48] Homo saptens. [49] Birds and reptiles. [50] Palaeontology.

APPENDIX . 727

Chapter 12: Population Biology

- [A] Long Answer Type questions :
- 1. (a) What do you mean by overpopulation and population explosion? (b) Discuss briefly the causes of overpopulation.
- Ans. (a) Overpopulation means a considerably high density of human population in an area. A dramatic increase in human population, size over a relatively short period of time, is known as population, explosion.
- (b) Overpopulation is basically due to a higher rate of birth than that of death Although currently the rates of both birth and death are declining, the decrease in birth rate is much less in comparison to the decrease of death rate. As a result of this, the human population is growing day by day. Moreover, application of science and technology to increase the availability of rife supporting resources has increased the earrying capacity of eight, which in turn favours population growth. The various causes of increase in human population, are summarised below.
- [1] Low death rate: In the past, growth of human population was re-tricked due to a finish death rate, particularly infant and child mortality. With the advancement of civilization and knowledge of science, death rate has been checked due to the following two reasons:—
- [a] Protection from nature Man has developed ways to protect himself from nature e.g. predators (wild animals), natural calamities and adverse effects of extreme climatic conditions (heat, cold *etc*).
- [b] Protection from severe diseases. Various diseases like small pox, choleia, malaria, tuberculosis plague etc., which were earlier not easily curable and were responsible for large number of deaths, have now been brought under control by discovery of newer medicines, antibiotics and vaccines. Many epidemic and endenic diseases have been erradicated. Immunization programmes have checked child mortality
 - [2] High birth rate: It is due to the following socio-economic reasons
- [a] Universality of marriage—As a common rule of human life, every one gets married and participates in reproduction.
- [b] Farly marriage A woman's reproductive age is roughly from 15 to 45 years. Naturally, early marriages increase the probability of more births.
- [c] Traditional customs. Many people believe that children are gift of god and their birth should not be restricted. Moreover, most of the couples desire to have at least one son because a son is thought to be an asset for security of the parents in future. So, those having one or more daughter(s) try again to get a son.
- [d] Low standard of living and lack of education. Buth rates are usually high where standards of living and education are low such as in developing countries and rural areas. This is because large number of hands are needed for performing low technology tasks, so poor and uneducated people do not have family planning habits. With the advancement of a country, as the technology improves and requirement of working hands is reduced, parents realise that having more children lowers the standard of hving, this realisation decreases birth rate.
- [3] Increased availability of resources: Knowledge of science has helped us to therease production and supply of food and other things needed for population. It is due to [a] improvement in agriculture (use of fertilizers and insecticides and

production of high yield crops), fishery, dairy, poultry farming ctc. and [b] development of means of transportation and techniques for storing food. All these facilities have supported an increase in human population.

[4] Migration: In developing countries like ours, the urban population has increased dramatically in few years. It is mainly due to migration of large number of people from villages to urban areas because of employment opportunities, attraction of better living standards, and availability of social services like education, health, transport, entertainment of Immigration from neighbouring countries (entry of relagees) is also an important cause of overpopulation.

2. Discuss briefly the adverse effects of overpopulation.

Ans. 1.R. Malthus (1778) proposed a theory of human population proxib According to this, when unchecked ,the hum in population grows geometrically ($t \in 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow$ and so on) whereas the means of its subsistence (food *etc.*) grow only arithmetically ($t \in 2 \rightarrow 4 \rightarrow 6 \rightarrow 8 \rightarrow 10$ and so on). This leads to madequacy of the means of subsistence for an exponentially growing population. It causes a large number of problems to a nation as well as to an individual family. The adverse effects of overpopulation, are as follows.

[11] Unemployment and poverty: Overpopulation leads to increase in unemployment and poverty. Advancement of technology reduces the need of manual work and thus scope of employment. So, workers get less salary and the per capita income is low About \$60% of the Indian population, are living below the poverty line.

[2] Shortage of food, shelter and clothing: Poor countries overburdened with population face an acute shortage of food, housing facilities and clothing. In our country, at least one fifth of the population, are under nourished or malnourished. Many people are homeless and live under the open sky.

[3] Low level of education and literacy: I ducation is a basic human right and is essential for economic and social development of a country. A person is said to be literate if he or she can read and write with understanding at least in any language. In overpopulated countries, large number of people remain unedicated and even illiterate. Poor people usually do not like to send their children to schools and prefer to engage them in earning money. As a result of this, the rate of drop out in the first few year of schooling is very high.

141 Unhealthy hygienic conditions: Overpopulated countries cannot provide proper health services to every citizen. Hospitals and health centres are usually madequate and thus overcrowded with patients, who do not get proper medical treatment. In such countries, many people live in slums having unhygienic conditions. Their children are deprived of love and proper care. So, in spite of the health care programmes of the government, the child mortality rate is high.

[5] Pressure on environment and pollution: Population explosion imparts a heavy pressure on the limited natural resources that are depleted day by day. Overpopulation is associated with intensive urbanisation, deforestation, use of fertilizers and pesticides for better agriculture, use of fossil fuels as source of energy and production of wastes. All these lead to pollution of environment, which is extremely bazardous to us

[6] Social problems: Overpopulation has led to a social imbalance between the the developed and developing nations. The per capita use of resources in a developed country is many times greater than that in a developing country. This has led to aggressive

natural resource acquisition, colonialisation and war. Excessive growth of population increases the occurrence of crimes in a society.

From the above discussion it is clear that overpopulation is a curse, particularly for the countries which are underdeveloped or in developing stage like our India. It hinders advancement and prosperity of a nation. So, it must be checked by implementing family planning programmes strictly.

3. How overpopulation is related to low level of education (literacy) in a country?

Ans, I ow level of education is a cause as well as an effect of overpopulation. In a country where the level of education is low, the birth rate is usually high leading to overpopulation. This is due to the lack of family planning habit in uneducated people because. (i) They believe that children are gift of god and asset for earning, so they desire to have more children. (ii) They are not conscious about the ill consequences of having more children and overpopulation. (iii) They are not aware of the methods of family planning.

Overpopulation in turn restricts the scope of education because: (i) The educational institutions (schools) cannot accommodate all children of a rapidly growing population (ii) In over populated countries, majority of people are poor; so they engage their children in earning money instead of sending them to schools.

4. 'Population problem' and 'pollution problem' are by-products of advancement of science. Explain.

Ans. Population problem is a by-product of advancement of science because the latter has supported growth of human population in two basic ways: (i) Advancement of medical sience has reduced mortality-rate and increased life expectancy (longivity) of man by providing ways and means to control epidemics and life-threatening diseases. (ii) Application of science and technology has increased the carrying capacity of the earth by increasing food supply (through development of better methods of food production as well as storage and transportation of food) and by providing other means of substinence e.g. housing, clothing, etc. for the growing population

Pollution is a man-made problem which is becoming more serious day by day with the advancement of science and technology leading to invention of new materials and new processes to meet the needs of the increasing number and the changing life style of man. Use of scientific inventions add large quantity and variety of wastes to the environment and pollute it. For example—smoke emitted from automobiles and industries pollute the atmosphere, industrial effluents and fertilizers and pesticides used in agriculture pollute the water bodies, use of nuclear energy pollutes air and water, and so on.

5. 'Do not mix drinking with driving'. Explain the statement with reasons.

Ans. The statement 'do not mix drinking with driving' is a very important warning for those who drive after consuming alcohol. Drivers of heavy vehicles on a long route often drink alcoholic beverages and then drive. This is dangerous, and may cause serious accidents leading to injury or death of many innocent people. Such accidents are due to the following effects of alcohol intoxication—(i) It affects correct judgement of distance—(ii) It affects coordination of hands, legs and eyes causing loss of control on driving—(iii) It impairs vision. The vision becomes blurred and unsteady, and the field of vision

is reduced which is known as tunnel vision. (iv) It reduces alertness of the body and thus increases the reaction time so that the driver fails to react quickly in unexpected situations causing accidents. (v) It affects behaviour; the intoxicated drivers are often very rash and careless, so they cause accidents.

• [B] Distinguish between:

1. Distinguish between Psychosis and Neurosis. Ans.

Psychosis	Neurosis
(i) It is the major mental illness. (ii) A psychotic patient is insane and out of touch with the realities of life. (iii) Such patients are not aware of their illness and they do not like to take any treatment.	(i) It is a minor mental illness. (ii) A neurotic patient is not insane and out of touch with reality but is unable to react and adjust in different situations. (iii) Such patients are well aware of their illness and they seek treatment.

2. Compare Tobacco addiction, Alcohol addiction and Drug addiction. Ans.

Tobacco addiction	Alcohol addiction	Drug addiction
(i) It is not illegal. (ii) It does not affect consciousness. (iii) It maximally affects the respiratory and cardiovascular systems.	(i) It is not illegal. (ii) It affects consciousness. (iii) It maximally affects the brain and liver.	(i) It is illegal. (ii) It affects consciousness. (iii) It maximally affects the brain.
(iv) It may cause cancer of respiratory tract or lung. (v) It is easy to give up the habit of consuming tobacco.	(iv) It may cause cancer of liver. (v) It is not easy to give up the habit of drinking alcohol.	(iv) It does not cause cancer.(v) It is very difficult to get rid of this addiction.

3. Distinguish between Active immunity and Passive immunity. Ans.

(i) In this, the antibody is produced in the body in response to an antigenic stimulus. (ii) For this, entry of antigen into the body of the individual is essential. (iii) It takes more time to develop. (iv) It is long lasting. (i) In this, an individual receives a readymade antibody (formed in another individuals body). (ii) For this, entry of antigen into the body of the individual is not required. (iii) It takes much less time to develop. (iv) It is short lasting.	Active immunity	Passive immunity
	the body in response to an antigenic stimulus. (ii) For this, entry of antigen into the body of the individual is essential. (iii) It takes more time to develop.	 (i) In this, an individual receives a readymade antibody (formed in another individuals body). (ii) For this, entry of antigen into the body of the individual is not required. (iii) It takes much less time to develop.

4. Distinguish between Primary immune response and Secondary immune response.

Ans.

(i) It occurs when an antigen enters into the body for the first time. (ii) It is a classification of the first time. (iv) It is a classification of the first time.	Primary immune response	Secondary immune response
	(ii) It is a slow process, <i>i.e.</i> it takes much more time to develop. (iii) In this, less antibody is produced:	(i) It occurs when an antigen enters into the body for the second time. (ii) It is a rapid process, i.e. it takes much less time to develop. (iii) In this, more antibody is

• [C] Short answer type questions:

1. Define—(a) Population, (b) Population size, (c) Population density and (d) Population growth.

Ans. (a) All the individuals of a particular species living within a specified habitat are collectively referred to as a **population**.

(b) Population size refers to the total number of individuals present in a population at a given time.

(c) Population density represents the total number of individuals of a population present per unit area or volume of the habitat at a given time.

(d) Population growth denotes the increase in the size of a population over a period of time.

2. What do you mean by—(a) Biotic community and (b) Biotic potential?

Ans. (a) All organisms (plants, animals and microbes) of different species living together in a given habitat are collectively referred to as biotic community of the habitat.

(b) The maximum capacity of an organism species to reproduce and increase in number under optimal conditions is called biotic potential.

3. What is maximum carrying capacity of an environment?

Ans. The maximum number of individuals of a species that can be supported by a given environment is referred to as maximum carrying capacity of the environment for the species.

4. What do you mean by human population?

Ans. The term human population refers to a group of human beings living in a given area such as a particular village or town or state or country or even the whole word.

5. What do you mean by 'population growth forms'? Mention their types.

Ans. Different populations have characteristic patterns of growth with time. These patterns are known as population growth forms. They are basically of two types J-shaped and S-shaped (or sigmoid).

6. What is a 'population growth curve'? What are its types?

Ans. A population growth curve is the graphical representation of a population growth form. It is obtained by plotting the size or density of a population at time intervals. It is of two basic types—J-shaped and S-shaped (or sigmoid).

7. Mention the phases of the J-shaped and S-shaped population growth curves.

Ans. J-shaped population growth curve has three phases—(i) initial lag phase of slow growth (ii) middle exponential phase of rapid growth and (iii) final crash phase.

S-shaped population growth curve has three phases—(1) initial lag phase (slow growth) (ii) middle exponential phase (rapid growth) and (iii) final stationary phase (zero growth)

8. What is doubling time of a population? How is it related to growth of the

population?

Ans. Doubling time of a population is the time required for a given size of population to double itself. It is inversely related with the growth of the population, *i.e.*, more the growth, less is the doubling time of a population.

9. Which country has the highest population?

Ans. China.

10. State reasons for the high birth rate in a country.

Ans. (i) Universality of marriage. (ii) Early marriages. (iii) Traditional customs. (iv) Absence of family planning habit due to low standard of living (poverty), low level of education, lack of motivation etc.

11. What are the reasons for decline in human mortality with advancement of civilization?

Ans. (i) Decrease in natural checks, e.g. famines, epidemics, predators (wild animals) etc. (ii) Mass control of diseases due to advancement of medical science. (iii) Better health facilities and national health programmes. (iv) Improvement of food supply. (v) Internal aid in various directions. (vi) Development of social consciousness among the people.

12. What are contraceptives?

Ans. Contraceptives are physical or chemical agents used to prevent unwanted pregnancies for birth control.

13. Name a physical barrier type contraceptive agent used by—(a) males and (b) females.

Ans. (a) Condom. (b) Diaphragm (or Cervical cap).

14. (a) What are oral contraceptives ? (b) Give two examples.

Ans. (a) Oral contraceptives are pills containing hormonal preparations, that are taken orally for the purpose of birth control.

(b) Combined pills, minipills.

15. What do the combined pills and minipills contain?

Ans. Combined pills contain synthetic estrogen and synthetic progesterone. Minipills contain synthetic progesterone only.

16. Name two IUCDs.

Ans. Lippes loop, Copper-T.

17. What is 'safe-period'?

Ans. Safe-period refers to those days of the menstrual cycle during which there is little chance of ovulation, so that coitus during this period does not cause pregnancy. It includes 1st to 7th day and 22nd to 28th day of the menstrual cycle counting the day of onset of menstrual bleeding as day-1 of the cycle.

18. Give the full names of—(a) IUCD, (b) IUD, (c) POP, (d) MTP.

Ans. (a) Intra-uterine contraceptive device. (b) Intra-uterine device. (c) Progesterone only pill. (d) Medical termination of pregnancy.

19. Mention four spacing methods of contraception.

Ans. (i) Withdrawal method, (ii) Use of physical or chemical barriers (e.g. condoms,

diaphragms or spermicidal agents etc.), (iii) Use of IUCD (e.g. Loop or Copper-T), (iv) Oral pill method.

20. Name two post-coital methods of contraception.

Ans. (i) Use of morning after pills (ii) Vaginal douching.

21. What is vasectomy?

Ans. Vasectomy is the surgical operation for permanent sterilisation of a male (i.e. for making the male permanently infertile) involving excision of a segment of each vas-deferens and ligation of the cut ends.

22. What is tubectomy?

Ans. Tubectomy is the surgical operation in which a segment of each fallopian tube is excised and the cut ends are ligated for permanent sterilization of a female.

23. Name the post conceptional method of contraception.

Ans. Medical termination of pregnancy (MTP) or induce abortion.

- 24. Name three methods of birth control that can be adopted by—(a) males and (b) females.
- Ans. (a) Withdrawal method, use of condom, vasectomy, (b) Use of diaphragms (vaginal caps), use of IUCDs (Loop or copper-T), Use of oral contraceptive pills, tubectomy (mention any three).
- 25. Name the common surgial methods of contraception adopted by—(a) males and (b) females.

Ans. (a) Vasectomy.

- (b) (i) Tubectomy, (ii) Surgical abortion.
- 26. Name the contraceptive agents which act by preventing—(a) ovulation, (b) implantation, (c) deposition of semen into vagina, (d) entry of sperms into uterus.
- Ans. (a) Oral contraceptive pills (combined pills and minipills), Subdermal synthetic progesterone implants. (b) IUCD, (Loop or Copper-T) (c) Condom. (d) Diaphragm (or vaginal caps), Spermicidal agents (pastes, creams, jellies, foam tablets etc.)
 - 27. Name the long-acting, temporary (reversible) methods of contraception.
- Ans. (i) Use of IUCDs (Loop, copper-T etc.) (ii) Slow-release subdermal implants of synthetic progesterone.
- 28. Name the mental illnesses in which the patient—(a) is insane and out of touch with the realities of life, (b) is unable to react normally to different situations of life, (c) lives in dream world, (d) shows occasional elation and depression.
- Ans. (a) Psychosis. (b) Neurosis. (c) Schizophrenia. (d) Mood disorder or Manic depressive psychosis.

29. What are psychotropic drugs?

Ans. Drugs acting on central nervous system and normally used for treatment of mental disorders are called psychotropic drugs (or mood altering drugs). These are also used for the purpose of addiction.

30. What is Psychotherapy?

Ans. Psychotherapy means counselling of a mental patient by a trained personnel to increase the mental strength of the patient so that he or she can adjust well to different situations of life.

31. What is electro-convulsive therapy?

Ans. Electro-convulsive therapy (or electroshock therapy) is a process of treatment

of mental patients in which electric current is passed through the brain of the patient to induce convulsions.

- 32. Name—(a) the chief toxic alkaloid present in tobacco, (b) the compound present in tobacco responsible for addiction to tobacco, (c) the compound present in tobacco smoke which causes poisoning of hemoglobin.
 - Ans. (a) Nicotine. (b) Nicotine. (c) Carbon monoxide.
- 33. Which compounds present in tobacco smoke are responsible for lung cancer in smokers?

Ans. Nicotine and polycyclic aromatic hydrocarbons.

34. Which systems of the body are worst affected by tobacco smoking? Ans. Respiratory system and Cardiovascular (or Circulatory) system.

35. Among tobacco smoking and tobacco chewing, which one is more harmful and why?

Ans. The chief toxic material present in tobacco is nicotine, which is consumed by both smoking and chewing of tobacco but smoking is more harmful than chewing because of the following two reasons—(i) In smoking, two additional toxic materials, carbon monoxide and polycyclic aromatic hydrocarbons, are also consumed. (ii) Chewing of tobacco causes harm to the chewer only but smoking not only harms the smoker, it also affects other people who passively inhale the tobacco smoke.

36. Which type of alcohol is present in alcoholic drinks?

Ans. Ethyl alcohol (or Ethanol).

37. Give the scientific name of the plants from which tobacco is obtained.

Ans, Nicotiana tabacum and Nicotiana rustica.

38. Which organ is maximally damaged by regular intake of alcohol in high doses?

Ans. Liver.

39. What do you mean by addiction?

Ans. Acquisition of habits such as smoking, drinking or consuming drugs leading to physical and mental dependence on these is called addiction.

40. From which word the term 'drug' has originated and why?

Ans. The term drug has originated from the French word drogue meaning a dry herb because most of the drugs are prepared fom dried herbs.

41. What is drug addiction?

Ans. Drug addiction is defined as a state of compulsion to take a psychotropic drug regularly, which is developed due to prolonged use of the drug by a person without any proper medical reason.

42. What do you mean by addictive drugs? Mention their main types?

Ans. Addictive drugs are psychotropic drugs (i.e. drugs acting on the central nervous system to alter the mental state and behaviour) which produce dependence and addiction as a result of their prolonged use. They are of four main types -depressants, stimulants, opiate narcotics and hallucinogens.

43. What are depressant drugs? Give two examples.

Ans. Depressant drugs are those psychotropic drugs which depress the activity of brain and are commonly known as sleep inducing drugs. Examples: Benzodiazepines, Barbiturates.

44. What are stimulant drugs? Give two examples.

Ans. Psychotropic drugs which increase mental alertness by exciting the nervous system are called stimulant drugs. Examples-Cocaine, Amphetamines.

45. What are opiate narcotics? Give two examples.

Ans. Opiate narcotics are psychotropic drugs which suppress brain activity and are used as analgesics (pain relieving drugs). Examples—Morphine, Pethidine.

46. What are hallucinogens? Give two examples.

Ans. Psychotropic drugs producing hallucinations (false visual or auditory sensations in absence of actual stimulation) are called hallucinogens. Examples—Cannabinoids, LSD.

47. What are cannabinoids?

Ans. Cannabinoids are addictive materials obtained from dried leaves and flowers of the hemp (*Cannabis*) plant, used to produce hallucinations. They include bhang, ganja, charas (or hashish) and marijuana.

48. Which addictive drugs are present in—(a) sleeping pills and (b) pep pills?

Ans. (a) Barbiturates and benzodiazepines. (b) Amphetamines.

49. Name the synthetic addictive drugs mentioning the groups to which they belong.

Ans. Name of the drug

(i) Barbiturates and Benzodiazepines

Group

Depressants.

(ii) Amphetamines
(iii) Pethidine and Methadone

Depressants.

Stimulants.

Opiate narcotics.

50. Name the addictive materials obtained from the following plants—(a) poppy

plant, (b) coca plant and (c) hemp plant.

Ans. (a) Opium, Morphine, Codeine and Heroin, (b) Cocaine, (c) Bhang, Ganja,

Ans. (a) Opium, Morphine, Codeine and Heroin, (b) Cocaine, (c) Bhang, Ganja, Charas (or Hashish) and Marijuana.

51. Which group of addictive drugs has no medicinal use?

Ans. Hallucinogens.

52. Name two addictive drugs that are clinically used as potent analgesics.

Ans. Morphine and Pethidine.

53. (a) Who first disovered vaccine? (b) Which vaccine did he discover?

Ans. (a) Edward Jenner. (b) Small pox vaccine.

54. Who discovered-(a) rabies vaccine, (b) oral polio vaccine?

Ans. (a) Louis Pasteur. (b) Sabin.

55. Give the full names of the following—(a) COPD, (b) LSD, (c) EPI, (d) WHO.

Ans. (a) Chronic obstructive Pulmonary disease, (b) Lysergic acid diethylamide.

(c) Expanded programme on immunization. (d) World health organization.

56. (a) What is the full name of BCG vaccine? (b) Which disease does it prevent? Ans. (a) Bacillus Calmette guerin vaccine, (b) Tuberculosis.

57. What is global immunization?

Ans. Global immunization refers to world-wide immunization programmes involving proper vaccination of all children of the world to protect them from six vaccine preventable diseases namely—diphtheria, whooping cough (pertusis), tetanus, polio, measles and tuberculosis.

58. What do you mean by antiserum? What is its use?

Ans. Antiserum means a sample of serum containing an antibody, obtained from the blood of an animal in which the antibody has been developed by injecting an antigen in small doses.

It is used to provide passive immunity to a person who has developed the disease caused by the antigen.

- [D] Multiple choice type questions :
- 1. Mortality refers to-
- (a) Birth rate, (b) Death rate, (c) Growth rate, (d) None of these.
- 2. Who proposed the theory of human population growth?
- (a) Edwards, (b) Jenner, (c) Malthus, (d) Hardin.
- 3. The maximum rate of reproduction of a species under optimum conditions is called—
 - (a) Carrying capacity, (b) Natality, (c) Population growth, (d) Biotic potential.
 - 4. The total number of individuals in a population is called-
- (a) Population size, (b) Population density, (c) Population dispersion, (d) Population growth.
- 5. The number of individuals of a population present per unit area or volume of the habitat is called—
- (a) Population size, (b Population growth, (c) Carrying capacity, (d) Population density.
 - 6. Which of the following is not a characteristic of a population?
 - (a) Growth form, (b) Natality, (c) Demography, (d) Dispersal.
 - 7. Doubling time is an index of-
- (a) Population density, (b) Biotic potential, (c) Population growth, (d) Maximum carrying capacity.
 - 8. The present rate of growth of world population per year is approximately—
 - (a) 1.0%, (b) 1.4%, (c) 2.0%, (d) 2.5%.
- 9. At present, the annual total addition to human population of the world is approximately—
 - (a) 25 million, (b) 50 million, (c) 70 million, (d) 92 million.
- 10. All the offsprings do not survive owing to shortage of food, disease, predation etc. This is termed as—
- (a) Biotic potential, (b) Fecundity, (c) Environmental resistance, (d) Carrying capacity of the environment.
 - 11. The human population of India in the year 2001 was-
 - (a) 683 million, (b) 860 million, (c) 950 million, (d) 1027 million.
- 12. Which one of the following is not a causative factor for population explosion?
- (a) Increase in longivity, (b) Decrease in famines and epidemics, (c) Increased poverty, (d) Increase in birth rate.
 - 13. Which one of the following is not caused by overpopulation?
- (a) Unhealthy hygienic condition, (b) Unemployment, (c) Pollution, (d) High birth rate.
- 14. Which one of the following is an effective measure to check human population?
- (a) Increasing agriculture, (b) Raising the age of marriage, (c) Increasing the scope of employment, (d) Discouraging the use of contraceptives.
 - 15. Which of the following methods of birth control is most effective?
- (a) Calender method, (b) Withdrawal method, (c) Oral contraceptive pill method, (d) use of spermicidal agents.
 - 16. Surgical sterilisation of a woman is called-
 - (a) Vasectomy, (b) Tubectomy, (c) MTP, d) Orchidectomy.

- 17. Which of the following prevents pregnancy by inhibiting ovulation?
- (a) Induced abortion, (b) Oral contraceptive pills, (c) Vaginal jellies, (d) IUCD.
- 18. Which of the following contraceptive measures can be adopted by women?

(a) Minipills, (b) Spermicidal agents, (c) Copper-T, (d) All these.

19. Which of the following birth control measures can be adopted by males?

(a) Tubectomy, (b) Diaphragm, (c) Combined pills, (d) None of these.

20. In which of the following methods of birth control, entry of sperms into the uterus is prevented?

(a) Induced abortion, (b) Tubectomy, (c) Both of these, (d) None of these.

21. Which of the following contraceptive measures acts by preventing implantation of the fertilised egg?

(a) MTP, (b) IUCD, (c) Cervical cap, (d) Condom.

22. Which of the following is a long acting contraceptive measure?

(a) Oral pills, (b) Loop, (c) Diaphragm, (d) MTP.

23. Which of the following conditions is true regarding mental illness called psychosis?

(a) The affected persons lose touch with reality, they are not aware of their illness and refuse to be treated. (b) The illness is characterised by fits and convulsions, loss of consciousness and falling down. (c) The affected persons show prolonged emotional excitement or depression, they are aware of the problem and seek help. (d) The affected persons cannot react normally to different situations of life.

24. Madness is medically termed as-

(a) Neurosis, (b) Psychosis, (c) Epilepsy, (d) Psychoneurosis.

25. Neurosis is a-

(a) Major mental illness, (b) Type of mood disorder, (c) Mal-adaptive mental disorder, (d) Type of insanity.

26. Which of the following is not used for treatment of mental illuesses?

(a) Electroshock therapy, (b) Psychotherapy, (c) Psychotropic drug therapy, (d) Steroid therapy.

27. Tobacco addiction causes diseases such as-

(a) Bronchitis and emphysema, (b) Gastric and duodenal ulcers, (c) Tachycardia and hypertension, (d) All of these.

28. The chief carcinogenic material present in tobacco smoke is—

(a) Carbon monoxide, (b) Nicotine, (c) Polycylic aromatic hydrocarbons, (d) None of these.

29. The physiological effects of nicotine are—

(a) Stimulation brain, (b) Release of adrenaline, (c) Both of these, (d) None of these.

30. Coronary heart disease may be caused by-

- (a) Tobacco addiction, (b) Drug addiction, (c) Both of these, (d) None of these.
- 31. COPD may be caused by prolonged consumption of—
- (a) Alcohol (b) Tobacco smoke, (c) Opium, (d) Cocaine.

32. Fatty liver is associated with-

(a) Tobacco smoking, (b) Alcoholism, (c) Drug addiction, (d) All of these.

33. Tunnel vision is caused by-

(a) Excessive smoking, (b) Excessive chewing of tobacco, (c) Excessive alcoholism. (d) None of these.

34. Which of the following is not of the same group in which the remaining three are included?

(a) Whisky, (b) Brandy, (c) Beer, (d) Morphine.

35. Which of the following is obtained from hemp (Cannabis) plant?

(a) LSD, (b) Opium, c) Pethidine (d) Marijuana.

36. Which of the following psychotropic drugs has no clinical use?

(a) Codeine, (b) Benzodiazepines, (c) LSD, (d) Morphine.

37. Ganja, bhang and hashis are classified as-

(a) Stimulants, (b) Sedatives, (c) Narcotics, (d) Hallucinogens.

38. Which of the following drugs is clinically used to relieve acute pain?

(a) Pethidine, (b) Barbiturates, (c) Marijuana, (d) Valium.

39. Which of the following drugs is derived from opium?

(a) Morphine, (b) Charas. (c) Barbiturates, (d) Cocaine.

40. Which of the following drugs can induce alertness and wakefulness?

(a) Cocaine, (b) Valium, (c) Morphine, (d) LSD.

41. A psychotropic drug inducing calmness, relaxation and drowsiness is—

(a) Amphetamines, (b) Caffein, (c) Valium, (d) Heroin.

42. Mood altering drugs are also called—

(a) Analgesic drugs, (b) Psychotropic drugs, (c) Antipyretic drugs, (d) Tranquillisers.

43. Which of the following is not an addictive drug?

(a) Caffeine, (b) Cocaine, (c) Aspirin, (d) Methadone.

44. An addictive psychotropic drug used in cough syrups is—

(a) Morphine, (b) Cocaine, (c) Amphetamine, (d) Codeine.

45. Which of the following can be used to prepare pep-pills?

(a) Barbiturates, (b) Amphetamines, (c) Codeine, (d) Pethidine.

46. Sleeping pills are made from-

(a) Cocaine, (b) Amphetamines, (c) Barbiturates, (d) LSD.

47. Heroin is a synthetic drug prepared from—

(a) Ganja, (b) Bhang, (c) LSD (d) Opium.

48. Cocaine is obtained from-

(a) Poppy plant, (b) Hemp plant, (c) Coca plant, (d) Fungus.

49. Which of the following is not a correct matching?

(a) Nicotine—Neurosis, (b) Ethanol—Cirrhosis of liver, (c) Polycylic aromatic hydrocarbons—Cancer, (d) LSD—Hallucinations.

50. The vaccine used for prevention of whooping cough is-

(a) OPV, (b) BCG, (c) ATS, (d) DPT.

51. Which of the following is not a correct matching?

- (a) Diphtheria—DPT vaccine,(b) Polio—OPV,(c) Tuberculosis—Tuberculin,(d) Tetanus—DPT vaccine.
- 52. Vaccination against which one of the following diseases is not included in global immunization programme?

(a) Polio, (b) Plague, (c) Pertussis, (d) Diphtheria.

- 53. Which one of the following vaccines is used to prevent more than one diseases?
 - (a) BCG, (b) DPT, (c) OPV, (d) None of these.
- 54. Which of the following can be used for active immunization against a disease?
 - (a) Vaccines, (b) Antisera, (c) Both of these, (d) None of these.

55. A vaccine contains-

- (a) Antigen, (b) Antibody, (c) Both of these, (d) None of these.
- 56. Which vaccine is used to prevent measles?
- (a) DPT, (b) BCG, (c) OPV, (d) None of these.
- 57. ATS is used for treatment of-
- (a) Typhoid, (b) Tetanus, (c) Tuberculosis, (d) None of these.
- 58. Which vaccine can prevent pertussis?
- (a) OPV, (b) DPT, (c) Both of these, (d) None of this.
- 59. Which of the following diseases cannot be prevented by vaccination?
- (a) Cholera, (b) Rabies, (c) Diphtheria, (d) Malaria.
- 60. Which of the following is a vaccine against tetanus?
- (a) ATS, (b) DPT, (c)BCG, (d) OPV.
- 61. Which of the following is a major type of mental illness?
- (a) Epilepsy, (b) Psychosis, (c) Neurosis, (d) None of these.
- 62. Mental disorders may be caused due to-
- (a) Changes in brain, (b) Home environment, (c) Hereditary factors, (d) All these.
- 63. The main addictive agent in tobacco is-
- (a) Nicotine, (b) Codeine, (c) Morphine, (d) Caffeine.
- 64. Alcohol is a-
- (a) Stimulant, (b) Depressant, (c) Analgesic, (d) All these.
- 65. Which of the following is a hallucinogen?
- (a) Morphine, (b) Heroin, (c) LSD, (d) Nicotine.

[64] Depressant. [65] LSD. [66] Cocaine.

- 66. Which of the following is not a derivative of opium?
- (a) Cocaine, (b) Morphine, (c) Heroin, (d) Pethidine.

Answers to Q. D

[1] Death rate. [2] Malthus. [3] Biotic potential. [4] Population size. [5] Population density. [6] Demography. [7] Population growth. [8] 1.4%. [9] 92 million. [10] Environmental resistance. [11] 1027 million. [12] Increased poverty. [13] High birth rate. [14] Raising the age of marriage. [15] Oral contraceptive pill method. [16] Tubectomy. [17] Oral contraceptive pills. [18] All these. [19] None of these. [20] None of these. [21] IUCD. [22] Loop. [23] The affected persons lose touch with reality, they are not aware of their illness and refuse to be treated. [24] Psychosis. [25] Mal-adaptive mental disorder. [26] Steroid therapy. [27] All of these. [28] Polycyclic aromatic hydrocarbons. [29] Both of these. [30] Tobacco addiction, [31] Tobacco smoke. [32] Alcoholism. [33] Excessive alcoholism. [34] Morphine. [35] Marijuana. [36] LSD. [37] Hallucinogens. [38] Pethidine. [39] Morphine. [40] Cocaine. [41] Valium. [42] Psychotropic drugs. [43] Aspirin. [44] Codeine. [45] Amphetamines. [46] Barbiturates. [47] Opium. [48] Coca plant. [49] Nicotine—Neurosis. [50] DPT. [51] Tuberculosis—Tuberculin. [52] Plague. [53] DPT. [54] Vaccines. [55] Antigen. [56] None of these. [57] Tetanus. [58] DPT. [59] Malaria. [60] DPT. [61] Psychosis. [62] All these. [63] Nicotine.

Chapter 13: Environmental Biology

• A. Long answer-type questions:

1. How plant succession helps in the transformation of an ecosystem?

Ans. Succession is a phenomenon by which one group of plant is replaced by another set of plants. It can be primary or secondary in nature and transformation of ecosystem or ecosere is observed in case of secondary succession. This can be explained in case of hydrosere, the original ecosystem is a water body inhabited by aquatic phytoplanktons, zooplanktons, plants and animals. The growth of *Sphagnum* or bog moss gradually transforms the water body in 2 ways. On one hand, it absorbs the water rapidly and on the other hand it forms gradual stratification on the surface of the water body. Soon that water body gets transformed into a peat land and gets inhabited by grasses and terrestrial species.

2. Why the food chain does not represent the actual ecosystem? How is it rectified?

Ans. The food chain represents a linear food-predator relationship between organisms in an ecosystem. It does not represent the actual ecosystem because it only considers one type of organism in an ecosystem.

It is developed in the form of food web because it considers more than one types of organisms in a trophic level. Thus the level of interaction between different organisms in a trophic level and between those belonging to different trophic levels becomes quite evident. But in order to express these interactions, it becomes a branched structure.

3. What is Ecological Niche? How can two organisms sharing the same habitat have different niches—Illustrate with example.

Ans. Ecological niche is the functional position of an organism in an ecosystem. It indicates the surrounding of an organism from where it derives its nourishment. It does not mean its habitat because Darwin observed in Galapagos that the finches were terrestrial, but some of them were procuring their food from the leaves, some from the bark and the rest from the ground. Similarly all the fishes live in a water body, but some are surface feeders, some are column feeders (i.e. procuring their food from the area in between the water surface and the bed) while the rest are bottom feeders.

4. Name three physical pollutants and also state their negative impact on human body.

Ans. The three physical pollutants are sound or noise, heat and radiation.

The noise above 120dB is harmful for human body, it causes irritation, hypertension, partial deafness and insomnia.

The heat liberated from cooling towers make the water hot. It is not only detrimental for the aquatic life, but it may cause burning effect in man. The increase in temperature may be harmful for the vital organs of human body.

The radiation can be of two types, *i.e.* ionizing and non-ionizing. The ionizing radiation like X ray, γ ray causes chromosome damage which may have broad carcinogenic action. The non-ionizing radiation like UV ray induces the formation of thymine dimer, uncontrolled formation of which can lead to skin cancer.

5. What is meant by SPM? How is it harmful?

Ans. The full form of SPM is suspended particulate matter. It can be of two major

types, viz. SPM₁₀ and SPM₂₅ having diameter of 10µ and 2.5µ respectively. The SPM₁₀ is less harmful directly but it forms aerosols, photochemical smog and thereby inhibits the entry of sun light into the lower atmosphere, reducing the primary productivity. It induces the formation of brown air composed of secondary pollutants and gray air, where the smog formation is incomplete.

The SPM_{2.5} is more harmful for human beings because it enters the lung and thus reduces the respiratory efficiency of the lung It also forms a micro-film on the lung tissue, where bacteria grow and reproduce and induce various respiratory diseases.

6. State the most important ground water problem in West Bengal. How it can be prevented?

Ans. The most important problem for ground water in West Bengal is the high level of arsenic in it. The WHO limit is 0.01 ppm in drinking water, but certain areas in the districts of Nadia and 24 Paraganas (N) of West Bengal have the arsenic level as high as 200 ppm. It is a slow killer, because its slow entry into the human body causes its deposition in the skin and soft tissue and ultimately induces skin cancer or melanoma. Arsenic prevention can be done in the following ways:

- (i) The deep tubewells spreading arsenic should he identified and sealed off.
- (ii) The surface water should be used for irrigation as well as drinking purpose.
- (iii) The activated alumina filters can be used.
- iv) Phyto remediation (As removal) can be brought about by certain plants like Azolla, Chlorella etc.

7. What are bio-indicators? How does they vary from bio-accumulators.

Ans. Bio-indicators are certain microbes which indicate definite type of pollution. As for example, lichens exhibit distinct colour change in presence of sulphur dioxide in the atmosphere and increase in SO₂ results in their destruction. So whenever the concentration of SO₂ is high, lichens cannot grow.

Bio-accumulators are those organisms which show selective absorption of a particular pollutant including heavy metals. As for example, some mushrooms like *Pleurotus* shows selective accumulation of cadmium and lead; grasses may accumulate lead, *Azolla* can accumulate arsenic, *Equisetum* shows selective absorption of gold. This type of accumulation can ultimately lead to biomagnification along the food chains.

8. What are the steps taken to prevent global warming?

Ans. Global warming increases in nature due to two reasons mainly, one is increase in the level of green house gases and the other one is the increasing amount of green house gases like carbon dioxide, methane, water vapour. The various steps that has been undertaken to prevent global warming are as follows:

(i) The aforestation programme has to be undertaken in the form of social forestry,

joint forestry programme.

(ii) The emission of green house gases has to be reduced.

(in) Industrial pollution is controlled by the use of treatment plant or better quality fuel.

(iv) The use of CFC and other freons are banned.

(v) The conventional fuel is replaced slowly step by step by non-conventional energy.

9. What are heavy metals? Illustrate the different cases of heavy metal pollution in West Bengal.

Ans. Heavy metals are those metals which have a specific gravity greater than 1,5.

e.g. cadmium, lead copper etc. Some specific cases of heavy metal pollution is West Bengal are arsenic, chromium, lead, cadmium.

Arsenic: Arsenic is present in the ground water in the districts of 24 Parganas (N) and (S), Nadia, Murshidabad. It is a slow killer and gradually accumulates in the soft tissues and blood of human body causing skin cancer. It can be prevented by activated alumina.

Chromium: Chromium mostly comes in the ground water from the effluents of leather tanneries and hexavalent chromium is most toxic. It damages soft tissue and may induce cancer. It is chemically converted to trivalent chromium.

Lead: Lead used to come from leaded fuel at one point of time, but with the discontinuity of leaded fuel, lead concentration has reduced.

It may be present in paints and affluents of paint industry. It is also present in cosmetics. The most important damge of lead is caused in the nervous system, it also blocks the synthesis of haemoglobin causing anaemia. Lead can be prevented by the use of unleaded gasoline, low lead cosmetics and paints.

Cadmium: Cadmium comes from the nickel cadmium battery plants. It can also come from mixed industrial effluents and municipal waste. It is both hepatotoxic and nephrotoxic, may damage the defence system of human hody brought about by WBC. It causes the Itai Itai disease in man. Cadmium can be prevented by proper recycling and safe disposal. Increase in zinc concentration may reduce the toxic effects of cadmium.

10. What is meant by ISO 14000 & ISO 14001? What is its importance?

Ans. The International Organization for Standardization 14000 series actually includes the industrial pollution management systems. The ISO 14001 certification to an industry denotes that it is an eco-friendly unit, where environmental pollution is under control.

The process involves preparation of a detailed report followed by pre audit by a pollution monitoring organization. Ultimately the environmental audit is carried out at a suitable date, where monitoring of pollution management systems are carried out, interviews are conducted with the authority, workers and the surrounding residents. Finally after all these formalities, when a company qualifies, the certification for EMS (environment management system) is given.

It is useful for carrying out business with other countries, to have the export licence. In addition to that the company enjoys additional incentives from the government for keeping pollution under control. Some ISO 14000 companies of India are ITC, Tata chemicals, TELCO, INDAL etc.

11. What is meant by bio-medical waste? How is it prevented?

Ans. Bio-medical waste means the waste materials generated from nursing homes, hospitals, fertility clinics and pathology laboratories. It include foetus, cotton, gauze, disposable syringe and needles, expired drugs etc. It is prevented by the Bio-medical Waste Act, 1998. According to this act:

- (i) Destruction of needle must be done after each use.
- (ii) The surgical gloves and materials should be destroyed after use.
- - (iv) The high risk waste should be burnt and thus human contact is prevented.
 - (v) The private clinics and patholagy laboratories should follow strict health norms.

• [B] Distingnish between:

1. Distinguish between Ecosystem and Ecological Niche:

Ans.

Ecosystem	Ecological Niche
(i) The structural and functional unit	(i) The functional position of an
of the nature is called Ecosystem.	organism in a habitat is known as ecological niche.
(ii) It can be classified on the basis of the habitat.	(ii) It can be classified as fundamenal niche, derived riche and multivarient niche.
(iii) The ecosystem includes producer, consumer and decompeser.	(iii) The ecological niche cannot be subdivided into components.

Producer	Decomposer
(i) The organisms capable of utilizing	(i) The detritus organisms capable of
solar energy via photosynthesis and	causing decay to living organisms
preparing food in the form of simple sugar.	returning the components back to natur
(ii) They initiate the process of energy	(ii) They help in the recycling of
flow.	materials from the biotic to the about
	components.
(iii) They include green plants and all	(iii) They include non-chlorophyllor
photo-synthetic organisms.	organisms like bacteria and fungi.
(iv) They occupy the base of an	(iv) They do not have any sepera
ecological pyramid.	position in an ecosystem, but is normal
5 11	present in every tophic level.
(v) They have the largest biomass in	(v) They have negligible biomass
an ecosystem.	comparison to that of the producers.

3. Distinguish between Ecological pyramid and Population pyramid

Ans.	
Ecological pyramid	Population pyramid
(i) The pyramidal representation of an ecosystem is called ecological pyramid.	(i) The pyramidal representation of the population of a particular place is ealled population pyramid.
(ii) These pyramids are mainly of 3 types, <i>i.e.</i> pyramid of number, pyramid of biomass, pyramid of energy. (iii) The components are producer, primary consumer, secondary consumer and tertiary consumers.	(ii) These pyramids are mainly of 3 types i.e. expanding age pyramid, stable age pyramid and diminishing age pyramid. (iii) The components are pre-reproductive group, reproductive group and post-reproductive group.
(iv) These pyramids are triangular, both upright and inverted in nature.	

4. Distinguish between Pollutant and Mutant :

Ans.

Pollutant	Mutant
(i) The pollutants include any material which are deposited in excess in the nature. (ii) The pollutants can be physical, chemical, heat, sound etc. (iii) Pollutants affect the nature including air, water, soil etc. (iv) Pollutants always exhibit certain damaging aspect.	(i) The mutants are materials which cause mutation. (ii) Mutaunts are physical or chemical in nature. (iii) The mutants affect the living organism. (iv) Mutants may be damaging or useful, as in case of plant breeding.

5. Distinguish between Ecotone and Ecotype: Ans.

	<u>L</u> Ecotype
(i) Ecotone is a transitional area between two different ecosystems. (ii) The mangrove represent an ecotone between terrestrial and aquatic ecosystem.	(i) Ecotype is a particular type of organism present in a specific ecosystem. (ii) Ecotype include tigers of Sundarbans and that of Corbett Park.
(iii) Ecotone seperates two different habitats.	(iii) Ecotype varies with the type of habitat.

6. Distinguish between Bio-accumulation and Bio-remediation: Ans.

Bio-accumulation	Bio-remediation
(i) The selective accumulation of a particular pollutant in an organism is known as bio-accumulation. (ii) The accumulation of heavy metals by soil borne mycelial fungi is a common example.	(i) The removal of a particular pollutant from the environment or its conversion to a non-toxic component is known as bio-remediation. (ii) The removal of metals or their conversion to insoluble forms by algae like Chlorella is an example.
7 Dt at 1 1 1	

7. Distinguish between Biofertilizer and Manure: Ans.

(i) It includes a group of nitrogen fixing arganisms like bacteria, cyanobacteria which fix atmospheric nitrogen. (ii) It includes cyanobacteria like Nostoc, Anabaena, bacteria like Azotobacteria, Clostridium. (ii) In includes semidecomposed plant materials which enrich the soil with nitrate, minerals and other elements. (ii) They include certain plants like Sesbania.

8. Distinguish between Biosphere and Biosphere reserve : Ans.

Biosphere	Biosphere reserve
(i) Biosphere is that part of atmosphere, hydrosphere or lithosphere where life exists.(ii) It is a natural part of the nature where living organisms exists.	

[C] Short answer type questions:

1. What is EPA?

Ans. The most powerful environmental protection act in India constituted in 1986.

2. Name an algal toxin.

Ans. Saxitoxin from Gymnodinium catenella.

3. When was the Nationl Environmental Tribunal Act passed? Ans. 17th June, 1995.

4. What was the first global convention against dumping of oil?

Ans. The first major convention against dumping of oil was the London Convention, 1972.

5. State the first air pollution act in India.

Ans. The Bomhay Smoke Nuisance Act, 1912.

6. Which Act was for the the first time passed against Industrial Pollution ? Ans. The factories Act, 1948.

7. What is the date of forest conservation act?

Ans. The forest conservation act was originally passed is 1927. It was revised in 1980.

8. Give a very simple definition for sustainable development.

Ans. As per the World convention for environmental development (WCED), 1987, sustainable development is a development that meets the need of the present without reducing the need for the future.

9. What is the other name for the Johannesburg world Summit?

Ans. The Johannesburg world summit (2002) is also called the World Summit on Sustainable Development.

10. What is the most common method for removal of arsenic or fluoride from drinking water?

Ans. Reverse osmosis.

11. What is the common method for removing pathogenic organisms?

Ans. The water is passed through a UV column.

12. Name two zooplanktons found close to the sea shore.

Ans. The two zooplanktons are:

Temora longicornis, Acartia erythraea, both belonging to phylum Arthropoda.

13. What is meant by euryhaline and polystenohaline zooplanktons?

Ans. Euryhaline zooplanktons are those which are tolerent to wide range of salinity.

e.g. Acrocalanus. Polystenohaline zooplanktons are those which are tolerent to high range of salinity. e.g. Oithona.

14. What is the cheapest way of removing arsenic from drinking water?

Ans. The cheapest way of removeng arsenic from drinking water is to pass it through a column of activated alumina.

15. Which pollution problem is associated with leather tanneries?

Ans. Hexavalent chromium pollution is a common problem associated with leather tanneries.

16. What is the chemical name for the common pesticide Lindane?

Ans. The chemical name for Lindane is Hexachlorohexane.

17. Why is Azolla grown in the paddy fields?

Ans. The aquatic pteridophyte Azolla harbours the nitrogen fixing cyanobacteria Anabaena azollae as an endophyte, which enriches the soil with nitrate, making it suitable for paddy plants.

18. What are the major types of SPM?

Ans. The two major types of SPM are SPM 2.5 and SPM 10.

19. State the major types of air pollutants coming from urban vehicular pollution.

Ans. Carbon dioxide, Carbon monoxide, Sulphur dioxide, Oxides of nitrogen, Polyaromatic hydrocarbons.

20. What are the major types of pesticides on the basis of their chemical constituents?

Ans. Pesticides are mainly of two types on the basis of their chemical constituents—viz. organochlorine compounds, e.g. DDT and organophasphate compounds, e.g. carbamate compounds.

21. How organophosphates work?

Ans. They block the enzyme choline esterase.

22. What are the major strategies adopted for the dispersal of radio-active pollutants.

Ans. The major strategies adopted for radio-active pollutants are:

delay and decay (for short lived nuclides), dilute and disperse (for. gaseous wastes) concentrate and contain (for high level solid wastes).

• [D] Multiple choice type questions :

1. The word ecology was coined by-

(a) Haeckel, (b) Tansley, (c) Darwin, (d) Lamarck.

2. The functional position of an organism in an ecosystem is-

(a) Ecosystem, (b) Ecotype, (c) Ecotone, (d) Ecological niche.

3. Xerosere originates in a-

(a) Grassland, (b) Desert, (c) Water body, (d) Forest.

4. The climax species in a psammosere is-

(a) Grass, (b) Timber trees, (c) Planktons, (d) Succulents.

5. Which one of the following places has the largest biodiversity?

(a) Desert, (b) Priaries, (c) Tundra, (d) Tropical rain forest.

6. The secondary treatment of water is-

(a) Physical separation, (b) Chemical treatment, (c) Biological treatment.

- 7. The example of degradable pollution is-
- (a) Heavy metal, (b) Pesticide, (c) Sewage.
- 8. The SPM is highest in-
- (a) New Delhi, (b) Mumbai, (c) Kolkata, (d) Chennai.
- 9. In power fuel, petroleum is mixed with-
- (a) Methyl alcohol, (b) Benzene, (c) Toluene, (d) Ethyl alcohol.
- 10. The example of a petroleum plant is-
- (a) Euphorbia, (b) Jatropha, (c) Poinsetia (d) Ricinus.
- 11. The removal of arsenic from water can be brought about by treatment of—
 - (a) Activated alumina, (b) Activated charcoal, (c) Silica gel.
 - 12. The atomic power is generated by-
 - (a) Nuclear fusion, (b) Nuclear fission, (c) β-particles.
 - 13. Minamata disease occurs due to toxicity of-
 - (a) Mercury, (b) Copper, (c) Methyl mercury, (d) Lead.
 - 14. The antiknock agent presently used in the petroleum mixture is-
 - (a) Benzene, (b) Toluene, (c) Lead oxide, (d) Ethylene.
 - 15. The increase of a particular pollutant along the food chain is—
 - (a) bioremediation (b) biological control, (c) biomagnification.
 - 16. The Man and Biosphere pragramme was launched by the UN in-
 - (a) 1973, (b) 1975, (c) 1982, (d) 1987.
 - 17. The component of the FC that actually causes ozone depletion is-
 - (a) Chlorine, (b) Fluorine, (e) Iodine.
 - 18. Ground water in the states of Bihar and UP may contain high amount of-
 - (a) Copper, (b) Arsenic, (c) Fluoride.
 - 19. The example of persistent organic pollutant is—
 - (a) Benzene, (b) Toluene, (c) PCB, (d) Ethylene.
 - 20. The movement of biosphere reserve was initiated in India in-
 - (a) 1976, (b) 1980, (c) 1986, (d) 1991.
 - 21. The example of a green house gas is—
 - (a) Water vapour, (b) Ozone, (c) Carbondioxide, (d) All of them.
 - 22. The term tinnitus is associated with-
 - (a) Air pollution, (b) Water pollution, (c) Noise pollution, (d) Radioactive pollution.

Answers to Q. D

- [1] Haeckel; [2] Ecological niche; [3] Desert; [4] Grass; [5] Tropical rain forest; [6] Biological treatment; [7] sewage; [8] Kolkata; [9] Ethyl alcohol; [10] Jatropha; [11] Activated alumina; [12] Nuclear fission; [13] Mercury;
- [14] Benzene; [15] Biomagnification; [16] 1973; [17] Chlorine; [18] Fluoride;
- [19] PCB; [20] 1986; [21] All of them; [22] Noise pollution.

Chapter 14: Applications of Biology

• [A] Long answer type questions:

1. What is biofertilizer? How cyanobacteria acts as biofertilizer?

Ans. The organisms which increase the nutrient availability to crop plants either directly or through soil enrichment are called biofertilizers.

Cyanobacteria help the crop plants as biofertilizer in the following ways: Two types of cyanobacteria are observed, such as *free living* and *symbiotic*. Both the types of cyanobacteria help in growth of crop plants.

- (a) Free living nitrogen fixing cyanobacteria: This type of cyanobacteria (blue green algae) namely Nostoc, Anabaena, Tolypothrix, Stigonema etc. grow freely in the soil. These cyanobacteria are photosynthetic in nature and can enrich the soil with nitrogen. Aulosira fertilissima, a cyanobacterium is widely used as a nitrogen fixer in the paddy fields all over India. Cylindrospermum licheniformis, a cyanobacterium is used in the sugarcane and maize fields. It contributes 30 44% of fixed nitrogen to the crop plants. In fact, it is estimated that a cyanobacterium can fix 20 30 kg/ha of nitrogen and that is sufficient to meet the requirement of paddy crop. Cyanobacteria has accounted for 100% saving of nitrogen fertilizers in Tamil Nadu, only supplementation of phosphate and potassium is required.
- (b) Symbiotic nitrogen fixing cyanobacteria: The nitrogen fixing cyanobacteria can develop symbiotic association with liver worts, ferns and cycad roots. Azolla punnata is an aquatic fern growing in the stagnant water of paddy fields. Its leaf cavities contain a nitrogen fixing cyanobacteria known as Anabaena azollae, which provides nitrogen to the rhizosphere of paddy plants. With the harvesting of the crop, the dried fern serves as a green manure. Thus it enriches the field for the next crop.
- 2. What is insecticide? Describe in short the classification of insecticides and how they act on insect pests.

Ans. Insecticide is a particular kind of pesticides for killing mainly insects.

According to the toxic effects on the site of insect pests, insecticides are classified into three groups, namely stomach poison, contact poison and fumigant.

(a) Stomach poisons: This type of insecticide enters the insect's body through the gastro-intestinal tract after being eaten by the treated insects. The reaction on the body of the insect pest is fatal. This is used against cockroaches and other crawling insects in the household. Example: Pyrroles.

Systemic insecticides have also been considered as true stomach poisons. This type of insecticides also act through the gut of the insect pests. After application of systemic insecticides on crop plants, they are translocated within the body of plants. Insect pests which feed on these plants come in contact with the insecticide through the gut. As a result, those pests are killed. Piercing and sucking type of insect pests are killed by systemic insecticides which are present in plants.

(b) Contact poisons: It is the major group of modern insecticides. These insecticides generally enter the body when the insect pests walk or crawl over a treated surface of leaves. The insecticide is then absorbed through the body wall. If the treated surface of plant such as leaf is a food source of insect pest, the insecticide enters the digestive tract of the insect pest during eating of treated leaf. The insecticide is then absorbed in

the body through digestive tract of the insect pest. But still the primary entry site of contact poisons from the environment is the body wall of insect pest. Example: Pyridaben.

(c) Fumigants: They are highly volatile contact insecticides. These insecticides act through the tracheal system of insect pests. Fumigant insecticides are applied to enclosures and to soil. These insecticides enter to the tracheal system and after being absorbed to the blood, they are circulated inside the body of the insect pest. Subsequently they are absorbed by the body tissues. Ultimately the insect pests are killed by the fumigant. Fumigants have high penetrating ability and kill all stages of insects in enclosures including their eggs in greenhouses, homes, warehouses and package products of beans, grains and dried fruits. Fumigants are also used against soil insect pests, nematodes and pathogenic micro-organisms. Thus the fumigants are used for the destruction of pests in confined spaces. Examples: Hydrocyanic acid gas, Carbon disulphide, Methyl bromide etc.

3. What is meant by mycopesticides?

Ans. There are different entomopathogenic fungi belonging to class Deuteromycetes like Beaveria bassiana, Metarhizium anisopliae, that destroy insect pathogens like Heliothis armigera, Spodoptera litura and thereby protect different crop plants. Some of these fungi like M. anisopliae, are resistant to benomyl or carbendazim fungicide, so thay can be active even in presence of fungicides.

These fungi can also be active against insect damaging the timber plants and thereby protect the timber yielding plants like teak (Tectona grandis)

Fungi like *Coelomomyces* and *Lagenidium* can destroy mosquitoes whereas. Verticillium and Tolypocladium are effective in controlling certain insect vectors.

4. What are the harmful aspects of chemical pesticides?

Ans. The harmful aspects of chemical pesticides are as follows:

- (i) It may cause residual toxicity to higher animals including man, which may include damaging of skin and soft tissue, nephrotoxicity, hepatotoxicity, damaging of sex organs.
 - (ii) It may cause non-target toxic effect to diferent beneficial microbes.
- (iii) It may be accumulated in different organisms of the food chain causing biomagnification.
 - (iv) It may alter defence responses of other plants to other pathogenic organisms.
- (v) In the long run, excessive use of pesticide might lead to the development of resistance in the target organisms.
 - (vi) It can directly contaminate food grains, vegetables and fruits.

5. What is pesticide? Write what you know about the disadvantages of pesticides to man and wildlife.

Ans. The term pesticide is derived from the Latin suffix, cida or 'killer'. Hence in broader sense, the term pesticide is denoting a killer of pests. Application of pesticides in agricultural fields no doubt increase the yield of crops by killing the pests. But indiscriminate use of pesticides invites the pest problems in a severe form and total devastation of crops may occur. It has also been noticed that the toxicity of pesticides can cause serious problems to man as well as wildlife populations in surrounding areas.

These problems in relation to man and wildlife are given below:

(a) Hazards or disadvantages to man: Pesticides are hazardous to human health. The degree of hazard or disadvantage depends on the toxicity of the pesticides and the

chance of exposure to the toxic amounts of the product. Thus pesticide causes two types of human poisoning, such as acute poisoning and chronic poisoning.

- (i) Acute poisoning: This type of poisoning occurs to persons who are directly involved in the manufacture of pesticides and application of pesticides to agricultural field. Acute poisonings also occur among non-professionals, such as in case of accidents, ignorance, suicide or crime. Acute poisoning causes illness or death from a single dose of exposure.
- (ii) Chronic poisoning: This type of poisoning occurs from a prolonged exposure to low levels of toxicants. Chronic poisoning reveals only after several weeks of exposure, as in case of DDT related compounds. These compounds are accumulated in dairy cows which fed on residue laden plants. Consequently, there is high residues of pesticide in the milk fat of dairy cows. Ultimately, men ingest pesticide through milk of affected cows. Repeated consumption of this type of milk can cause sickness or death of man. Thus the toxic residues in foods and on plants cause hazards to man.
- (b) Hazards or disadvantages to wildlife: Increasing use of pesticides cause adverse effects on wildlife. Pesticide which is used to kill aphids in sugarbeet causes the death of many birds specially pheasants and patridges. There is widespread use of insecticides (aldrin, dieldrin etc.) for the seed treatment of wheat to control wheat bulb fly. The treated grain was often taken by birds; as a consequence of which there was death of large number of birds. Thus there was an alarming increase of deaths of graineating birds. Sometimes treated grains are scattered in the field and the game birds and other desirable species eat those treated grains. As a result, those important species are also killed. These contaminated birds are eaten by predator mammals and birds. Failure of some predator birds to breed successfully has been claimed to be caused by pesticides. It cannot be denied that pesticides are toxic to fishes, birds and mammals. Hence, we can say that pesticides cause disadvantage or hazard to wildlife.

6. How transgenesis helps in the development of disease resistant crops?

Ans. The transfer of genes from different microbes with the help of microbial vectors may confer resistance against different microbial pathogens. Some of these cases are illustrated below:

- (i) Resistance against virus: The DNA segment responsible for the production of protein coat of TMV is identified and its transfer to the tobacco plant, confer resisistance against the aforesaid virus.
- (ii) Resistance against bacteria: The lysozyme producing gene from silk moth, when transferred to crop plants, make them resistant against pathogenic bacteria.
- (iii) Resistance against fungus: Fungal resistance may be brought about by increasing the production of phytoalexin, activating the pathogenesis related proteins or by the inactivating fungal ribosomes.

7. What is totipotency? What are its applications?

Ans. The ability of a particular cell of an organism to regenerate itself into a complete organism is known as totipotency. The plant cells from the meristematic region are otipotent, similarly animal stem cells are also totipotent.

The different applications of cellular totipotency are as follows:

(i) Production of plant callus, which can be used in the regeneration of the plant.

- (ii) Preparation of cell suspension cultures in plants and animals for maintenance of a particular cell line.
 - (iii) The naked protoplast obtained can be used for the purpose of fusion.
 - (iv) The property can be used to get a haploid plant.
- (v) The animal cells can be used to regenerate the entire organ and thereby resolve the issue of organ transplant in man.
- 8. What are the uses of X Ray? What are its demerits? How it has been replaced in the present day?

Ans. The high degree of penetrability of X Ray is used in the imaging of internal organs, position of the foetus and internal fractures, osteoporosis, histological changes involved in osteoorthritis. It can also detect infections of the chest including tuberculosis. It is also very useful in dentistry, particularly before dental surgery. It can also detect malignant changes of an organ.

The major demerit of the use X Ray is that, repeated use of X Ray results in the incidence of the adverse effects of irradiation and may induce cancerous changes in adults, damaging of the foetus *etc*.

Presently it is replaced by ultrasonograply, which is only detection of a physiological disorder with the help of sound waves. On the basis of its reflection, the imaging is done and so it is also safe for the developing foetus.

9. What is endoscopy? What are its different facets?

Ans. Endoscopy is a method by which photographs of internal organs are taken. It consists of 2 optic fibre lines, one connected to a light and the other is connected to a camera for the purpose of imaging.

It is also used for the purpose of biopsy, detection of tumor, removal of gall stone etc.

It is classified as:

Study of Joints-Arthroscopy.

Study of bronchus-Bronchoscopy.

Study of Colon-Colonoscopy.

Study of Cervix-Colposcopy.

Study of Urinary bladder-Cystoscopy.

Study of Gastro Intestinal tract—Gastroscopy.

Study of Rectum-Proctoscopy.

Study of thorocic cavity—Thoracoscopy.

10. What is ECG? What is it denoted?

Ans. ECG is the abbreviated name for Electrocardiograph. It is an instrument which records the electrical discharges generated during the contraction and relaxation of heart.

The atrial and ventricular events are denoted by six consecutive waves in the form of P, Q, R, S, T and U curves. The P-wave denotes atrial depolarisation, QRS complex denotes ventricular depolarisation, the T wave shows ventricular repolarisation and U wave represents atrial repolarisation. The U wave is not always denoted separately because it gets superimposed with the QRST waves. Any deviation from this normal wave pattern indicates some pathological conditions of the heart.

11. What is PET scan? How is it advanced over normal CT scan?

Ans. The full form of PFT scan is positron emission tomographic scan. The positron emitting radio-isotopes are used in this purpose which include "C, "N, "O etc. These radio-isotopes are incorporated into various compounds like glucose, amino acids and those are taken in by the patients. These compounds are distributed in the various internal organs. The 3 dimensional images are taken up by PET cameras and the images are reconstructed by the computer. It is advanced over ordinary CT scan or computed tomographic scan because it can provide quantitative information on the metabolic and physiological processes of the tissues and organs

12. What is a heart lung machine? How does it vary from ventilator? What are the uses and demerit of this machine.

Ans. The heart lung machine is also called pump oxygenator. It operates the heart and lung during major surgical procedures like open heart surgery. The principle is that blood is drawn out from the vein and after oxygenation, the blood is returned back to the arteries. During this operation, the normal contraction of the heart is stopped by passing potassium citrate through the coronary vessels. Aventilator is different from a heart lung machine because it only helps in the working of the lung through active infusion of respiratory gases with the help of a bellow. A heart lung machine is the major survival instrument for a patient undergoing coronary by-pass surgery.

It not only helps to run the heart and lung during operation, but also clears the vision during the open heart surgury. It also helps in early post surgical healing of the

Presently heart lung machine is not always used in coronary by-pass surgery or open heart surgery because its use may result in the loss of huge amount of blood. Moreover, the patient may develop dependence to the machine

[B] Distinguish between:

1. Distinguish between Biotechnology and Bioinformatics: Ans.

Biotechnology **Bio-informatics** (1) The method by which the transfer (1) Bio informatics is the informations of gene takes place with the help of a microbial vector, resulting in the production of transgenic organism.

- (ii) The major areas of bio-technology are recombinant DNA technology, tissue culture.
- (iii) It is mainly carried out in the wet lab.
- (iv) Products in terms of enzymes, fuels, medicines, biofertilizers are developed.
- available in worldwide web, in terms of protein and gene structure which is assimilated together to determine the structure of unknown molecule or organism.
- (ii) The major areas include study of protein or proteomics and gene study or genomics.
- (iii) It is carried out in the dry lab with the help of computers.
- (iv) Products are not developed directly but are identified, characterized and improved.

2. Distinguish between Microbial Vectors and Insect Vectors :

Ans.

Microbial Vector

- (i) They are specialized microbes, involved in the transfer of a desired gene fragment from one organism to the other.
- (ii) These vectors should have adequate number of plasmid DNA.
- (iii) The transfer of gene is utilized artificially for the production of artificial transgenic organisms.
- (iv) They include bacteria like Escherichea coli, Agrobacterium tumefanciens

Insect Vector

- (i) They are specific insects which help in the transfer of a pathogenic microbe from one host to the other
- (n) These vectors should have well developed mouth parts which usually carry the infective organisms including virus.
- (iii) They help in the natural transfer of pathogenic organisms.
- (iv) They include mosquitoes, houseflies disseminating diseases like malaria, filaria, cholera etc.

3. Distinguish between Plastic and Bioplastic :

Ans.

Plastic

- (i) They are organic polymers, produced by the polymerization of compounds like ethylene.
- (ii) These compounds are non-biodegradable and hence cause pollution.
 - (iii) They are produced at a low cost.
- (iv) They are obtained from chemical compounds.

Bioplastic

- (i) They are generated by microbes including bacteria capable of producing compound like polyhydroxy alkanoates.
- (ii) These compounds are biodegradable because of their biotic source and hence do not impart pollution.
- (iii) The production cost is higher as it involves transgenesis.
- (iv) They are obtained from bacteria like Chromobacter violaceum.

4. Distinguish between Gene cloning and Gene mapping

Ans.

Gene cloning

- (i) It is a process by which a desirable gene is identified in an organism, it is isolated, polymerized and replicated to produce a gene bank.
- (n) Gene cloning involves techniques like Restriction fragment length polymorphism (RFLP), Polymerase chain reaction (PCR).
- (iii) Gene cloning is involved in the production of transgenic organisms.

Gene mapping

- (i) The process by which a particular gene is identified in a chromosome and its functional aspect is determined using molecular markers.
- (11) Gene mapping involves the techniques of the study of family linkage groups, segregation of cell hybrids, use of molecular markers, RFLP.
- (iii) Gene mapping is carried out for the identification of a gene and may be useful in the preparation of molecular markers or in gene therapy.

5. Distinguish between Meristem culture and Haploid culture :

Ans.

Meristem culture

- (i) It is prepared from the menstematic cells of the shoot tip or root tip or leaf tip.
 - (ii) It is diploid in nature.
- (iii) It mainly grows into a callus culture and ultimately differentiates into root or shoot, because of the application of the hormone
- (iv) It is used to regenerate the entire plant.

Haploid culture

- (1) It is prepared from the pollen grains of matured flowers
 - (ii) It is haploid in nature.
- (iii) It grows as a suspension culture and may not differentiate into an entire plant.
- (iv) It is used for fusion of different cell lines.

6. Distinguish between Flectrophoresis and Electroporesis:

Ans.

Elecrophoresis

- (i) The process by which a complex protein or a large DNA molecule is | technique involving insertion of a desired separated into its constituent components depending upon their charge or molecular
- (ii) The process can be of 3 types i.e. DNA, RNA and protein
- (iii) It is employed in the characterization of an organism or in the preparation of a DNA imperprint with the help of blotting.

Electroparesis

- (i) Electroporesis is a biolistic gene fragment into the DNA of the host cell with the help of a plastic bullet.
- (11) The process cannot be classified because it is only involving insertion of DNA fragments.
- (iii) It is a modern technique having very high precision involved in the production of transgenic organism.

7. Distinguish between CT Scan and PET scan: Ans.

CI Scan

- (i) The full form is computed tomographic scan, which is much older.
- (ii) The technique involves imaging of the internal organs with the help X Ray
- (iii) The process does not give any information on metabolic and physiological changes in the human body.

PET scan

- (i) The full form is positron emission tomographic scan.
- (ii) The technique involves imaging of the internal organs with the help of positrons generated from various radioisotopes like "C, "N, "O etc.
- (iii) The process involves incorporation of positrons into tissues or organs and thereby it can give valuable informations about flow of fluid. metabolic rate.

8. Distinguish between ECG and EEG:

Ans.

ECG FFG

- (i) The full form is electrocardiogram.
- (ii) It helps in the recording of the electrical events of the heart during systole and diastole.
- (iii) There are 6 major waves in the graphical representation, viz. P, Q, R, S, T and U.
- (iv) The waves clearly denote the events of the cardiac cycle.
- (v) It is used to denote irregularities of the heart like heart attack, heart block etc.

- (i) The full form is electroencephalogram.
- (ii) It helps in the recording of electrical events generated by millions of neurones in the brain.
- (iii) There are 4 major types of waves, viz. alpha, beta, theta and delta waves.
- (iv) The events are not clearly denoted.
- (v) It indicates irregularities of the brain like cerebral attack, epileptic attacks etc.

• [C] Short answer type questions:

1. What is biofertilizer? Cite an example.

Ans. The organisms which increase the nutrient availability to crop plants either directly or through soil enrichment.

Example: Nitrogen fixing bacteria, such as Azotobacter

2. What do you understand by 'symbiotic nitrogen fixing bacteria'? How it helps the crop plants?

Ans. These bacteria form a symbiotic association with the root of higher plants. They grow in the root nodules of legume plants

They help the crop plants by fixing nitrogen while growing in the nodule, such as *Rhizobium*.

3. What is manure? How it helps the crop plants?

Ans. Manure is a semi-decomposed organic matter which is added to the soil Manures can change the soil texture and help in maintenance of air and water in the soil. It provides different types of nutrients to crop plants.

4. (a) How insecticides are classified on the basis of chemical make up? (b) Write the benefit of any one of them.

Ans. (a) Insecticides are grouped on the basis of their chemical make up. Several classes of compounds are designated according to their active ingredients which are responsible for the toxic effect. There are three major classes. (i) pyrethroids, (ii) carbamates and (iii) organophosphates.

(b) Organophosphates: This group of insecticide is beneficial for agriculture as well as garden and household purposes. Now the organophosphates are widely used. This group of insecticide is effectively used for aphids, leathoppers and piercing and sucking type of insect pests. It is commonly used for human louse. Organophosphate group is used safely against garden and household pests.

5. How the toxic residues of pesticides affect the soil?

Ans. After application of more persistent types of pesticides (such as organochlorine or organobromine compounds) to plants or soil, residues may persist in the soil for months or years together and by successive applications of those pesticides more and

more toxic residues are accumulated there. This increasing concentration of toxic residue damages the root systems of sensative plants, as well as small amount of toxic residue is absorbed by plants, which are later consumed by man and domestic animals. The toxic residues also modify the soil texture, pH, moisture, temperature, microbial activity etc.

6. How the pests develop resistance agains pesticides?

Ans. Resistance to pesticides has been observed in many species of insects, mites and rats. The possible means by which this resistance is achieved by pests are given below:

(i) The behaviour of insects is changed, so that pests avoid contact with insecticide.

(ii) Insecticide fails to reach the site of action of pest.

(ni) The toxic effect of pesticide reaches the site of action of the body, but this toxicity is detoxified by some metabolic process inside the body of pests.

7. What is Green Data Book?

Ans. Green Data Book is the name given to the book dealing with rare plants which are growing in protected areas.

8. How wild species will disturb the natural balance?

Ans. Heterotrophic animals are depended for food either on plants or on other herbivorous animals. If one of the heterotrophic organisms of a food chain decreases, the other organism will flourish. As a result, the natural food chain will be disturbed and produce harmful effects on the human society. Hence increase or decrease of primary or secondary consumers will disturb the food chain in nature and cause damage to the crops and vegetables or man and domestic animals. It the random killing of wild animals continue, the balance of oxygen and carbon di-oxide of the atmosphere will be disturbed, then the very existence of man on earth will be in great danger.

9. Write down the main reasons of declining of wild species.

Ans. Many of the wild species both animals and plants have already been extinct and many are threatened to be extinct due to various reasons given below:

(a) Hunting, (b) Habitat destruction, (c) Introduction of exotic species, (d) unscientific use of marine and freshwater species and (e) International trade.

10. Define apiculture. Mention the different species of honey bee.

Ans. Apiculture is the technique of scientific rearing of honey bees and extracting honey and wax from their hives.

There are three recognised species of bees in India and one recognised European species. Their scientific names are given below:

Indian—(i) Apis dorsata (Rock bee) (ii) Apis florea (Little bee) (iii) Apis indica (Indian bee)

European-Apis mellifica.

12. What is the importance of nod gene and nif gene?

Ans. Nod gene helps in the induction of nodule in the root of legume plants. Nif gene activates the process of nitrogen fixation in the nitrogen fixing organisms.

12. What is amniocentesis? Why was it discontinued?

Ans. Anmiocentesis is a process by which the amniotic fluid is taken out and the congenital abnormality in the foetus is detected. It was discontinued because the process was misused for determination of sex of the foetus and the female foetuses were destroyed.

13. What is blotting?

Ans. Blotting is a biochemical technique by which the DNA, RNA or protein molecules separated in a gel medium are transferred to nitrocellulose paper by the method of blotting.

14. What are the different types of blotting?

Ans. There are 3 types of blotting: Southern blotting for separation of DNA, Northern blotting for RNA and Western blotting for protein.

15. What is ELISA?

Ans. The full form of ELISA is enzyme linked immunosrbent assay. In this process a specific antibody is detected in human blood after binding with a specific antigen coupled with colour change brought about by a specific enzyme added to the mixture. It is used to detect specific antibody produced against AIDS virus or Hepatitis B virus.

16. What is gugulip?

Ans. It is an antilipid drug containing Z guggulusterone obtained from guggul leaf, patented in India.

17. How antimalarial vaccine has been produced?

Ans. The circumsporozoit protein (Pf-CSP) isolated from *Plasmodium falciparum* is used to activate the immuno response against malignant malaria in man. This can be referred to as antimalarial vaccine.

18. What is CD, protein?

Ans. The specific protein present in the membrane of helper T lymphocyte is CD₄ protein. It is recognized by the HIV in order to enter the lymphocytes.

19. Deficiency of which protein prevents Rheumatic arthritis.

Ans. Rheumatic arthritis is caused by streptococcal infection of the soft tissue which releases an endotoxin into the collagenous tissue causing rheumatic arthritis at a later stage. The absence of M_1 protein in the cells of collagenous tissue prevents the entry of Streptococcus into the collagenous tissue and prevents rheumatism.

20. What are mycopesticides?

Ans. The fungi that destroy insect constitute the mycopesticides. This may be either by the troduction of toxin or by blocking insect circulation. Example of two such fungi are Beauveria bassiana, Isaria felina.

21. Name a chemical agent which blocks the fatty acid biosynthetic pathway in malarial parasite.

Ans. Tricolsan.

22. How AIDS can be controlled through altered immuno response?

Ans. AIDS can be altered by modifying the immuno response from CD₄ to CD₈.

23. What is Ech rice?

Ans. The Ech 42 gene from *Trichoderma harzianum* capable of producing endochitmase enzyme is isolated and transferred to rice plant to produce Ech rice, which can produce endochitmase and destroy fungal pathogen.

28. What is Bt sorghum?

Ans. The transgenic sarghum capable of producing Bt toxin is known as Bt sorghum. It is resistant against Sorghum stem borer or *Chilo partellus*.

25. What is monellin?

Ans. It is a sugar free sweetner obtained from a yeast like unicellular fungi Monelinia.

26. What is SOD?

Ans. The enzyme superoxide dismutase reduces free radical effect in higher organisms and prevents aging.

27. What is the product generated by MTLT gene?

Ans. Manitol, which helps in resistance against drought stress by conserving water.

28. Name the organism producing B_s toxin.

Ans. Bacillus sphaericus.

29. Name the first test tube baby.

Ans. Louise Joy Brown born in Lancashire, UK on 25th july, 1978.

30. What is the total number of genes present in human?

Ans. As per the latest report of Human Genome Project, the total number of genes in man is 25000.

31. Which cells of plants are non-totipotent in nature?

Ans. The cells of vascular tissues are non-totipotent in nature.

32. Which hormone in plant delays senescence?

Ans. Cytokinin.

33. What is the full form of MET?

Ans. Magneto encephalographic tomography.

34. State the phenomenon on which USG works?

Ans. The sounds of USG are generated by applying electric potential to lead zirconate, which is called piezoelectric effect.

35. Who denoted MRI?

Ans. MRI or magnetic resonance imaging was denoted by Block and Purcell in 1946.

36. What is Stoke Adams syndrome?

Ans. The other name for heart block is stoke Adams syndrome, which is treated by artificial pacemaker.

• [D] Multiple choice type questions :

1. In biofertilizer, free living nitrogen fixing cyanobacteria includes—

- (a) Azospirillum lipoferum, (b) Rhizobium lupini, (c) Aulosira fertilissima, (d) Azolla pinnata.
- 2. Insecticide which is highly volatile and act through tracheal system of insect is known as—
 - (a) Systemic insecticide, (b) Stomach poison, (c) Fumigant, (d) Contact poison.

3. The first cultivation and domestication probably took place in-

(a) South-east Asian countries, (b) Tropical American countries, (c) South-west Asian countries, (d) East Europian countries.

4. Through the Rhinoceros project, Indian Rhinos are now protected by West Bengal Govt. in the—

- (a) Corbett National Park, (b) Dachigam Sanctuary, (c) Gir Forest, (d) Jaldapara Sanctuary.
 - 5. Dodo bird has become extinct from the country which is known as—

(a) Mauritus, (b) India, (c) North America, (d) South America.6. Single horned Rhino is available only in the forest of—

(a) Africa, (b) India, (c) China, (d) America.

7. Which of the following on dangered animals is conserved in Kanha National Park of Madhya Pradesh?

(a) Lion, (b) Rhinoceros, (c) Tiger, (d) Crocodile.

8. In India, about one kilogram of raw silk is obtained from nearly—

(a) 5kg. of green cocoons, (b) 16kg. of green cocoons, (c) 10kg. of green cocoons, (d) 20kg. of green cocoons.

9. In Mulberry silk moth, the silk thread is composed of-

(a) Protein, (b) Carbohydrate, (c) Fat and oil, (d) Mineral substance.

10. The larvae of Bombyx mori feed only on leaves of the plant-

(a) Morus sp. (b) Shorea robusta, (c) Ricinus communis, (d) Litsaea polyantha.

- 11. The discovery of the principle of movable wooden frame hive for bee keeping was made by—
 - (a) W. K. Roentgen (1895), (b) Rev. Langstroth (1851), (c) John Gibbon (1937),

(d) G. Hounsfield (1972).

- 12. The members of lac insect secrete a substance which is known as-
- (a) Honey, (b) Fibroin, (c) Resinous substance, (d) Sericin.
- 13. Name of a mycopesticide producing fungi is-
- (a) Beauveria, (b) Isaria, (c) Both.
- 14. The example of a organophosphate pesticide is-

(a) DDT (b) BHC (c) Demicron.

- 15. The fungi capable of producing endochitinase is-
- (a) Trichoderma, (b) Aspergilus, (c) Penicillium.
- 16. The host plant of bee insect is-
- (a) Kusum, (b) Arjun, (c) Neem.
- 17. The example of single cell protein is-
- (a) Candida (b) Spirulina, (c) Saccharomyces, (d) All of them.
- 18. Oryzolaxin is a -
- (a) Toxin, (b) Protein, (c) Enzyme, (d) Phytoalexin.
- 19. Interferons are active against-
- (a) Viruses, (b) Bacteria, (c) Protozoa,
- 20. DNA finger print was denoted for the first time by-
- (a) Southern, (b) Mullis, (c) Jeffrey.
- 21. Example of a weedicide is-
- (a) IBA, (b) NAA, (c) 2,4-D.
- 22. The coconut milk contains-
- (a) Auxin, (b) Gibberellin, (c) Kinetin.
- 23. The father of electrocardiography is—
- (a) Waller, (b) Einstein, (c) Einthoven.
- 24. Peizo-electric effect is observed in-
- (a) USG, (b) CT scan, (c) PET scan.
- 25. The technique of fluoroscopy is based on-
- (a) Staining, (b) X Ray, (c) Both.
- 26. The Nobel Prize for MRI was given to-
- (a) Block, (b) Purcell, (c) Lauterbar.
- 27. The haemodializer is attached to-
- (a) Pulmonary vein, (b) Radial vein, (c) Renal vein, (d) Brachial vein.
- 28. Mediastinoscope is used in-
- (a) ECG, (b) EMG, (c) EEG, (d) Pacemaker.
- 29. Pump oxygenator is the other name for-
- (a) Dializer, (b) Heart lung machine, (c) Ventilator.

- Answers to Q. D

- [1] Aulosira fertilissima. [2] Fumigant. [3] South-east Asian countries. [4] Jaldapara sanctuary. [5] Mauritus. [6] India. [7] Tiger. [8] 16 kg. of green cocoons. [9] Protein.
- [10] Morus Sp. [11] Rev. Langstroth (1851). [12] Resinous substance. [13] Both. [14] Demicron. [15] Trichedgema. [16] Kusum. [17] All of them. [18] Phytoalexin.
- [14] Demicron. [15] *Trichoderma*. [16] Kusum. [17] All of them. [18] Phytoalexin. [19] Viruses. [20] Jeffrey. [21] 2, 4–D. [22] kinetin. [23] Einthoven [24] USG.
- [25] Staining. [26] Lauterbar [27] Radial vein. [28] Pacemaker. [29] Heart lung machine.

11. The discovery of the principle of movable wooden frame blve for bee keepin was made by-(a) W. E. Rossinger (1885), (a) Kaw Laussian (1881), (c) John Gildon (1977)

(a) G. Houndird (1972) bladen on the control of the Fig. The members of his invest werete a salutione which is known as-

13. Name of a mycopesifelds producing first territi-

(a) Bearweria, (b) Jeures in Rome

14. The example of a organophosphare postable had it

15. The langi capable of producing andochimase is ______

(a) Trichoderma, (b) Aspecyalia, (c) Polycolling.

is, The host plant of bee insect is -

18 Oryman Sea - watering to a

27. The bacundisheer is stracked in-

29. Funip oxygenator is the other name, for-

Answers to Q. D [25] Steining. [26] I are Stein [27] Ramid vons. [25] Reger iven [29] Heart B



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